Volume 10 Number 2

BULLETIN

of the

American Association *of* Petroleum Geologists

FEBRUARY
1926

RAYMOND C. MOORE
EDITOR

PUBLISHED BY THE ASSOCIATION
CHICAGO, ILLINOIS

THE BULLETIN

of the

AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

The Bulletin of the American Association of Petroleum Geologists is published on or about the 15th of each month by the Association, at the University of Chicago Press, 5750 Ellis Avenue, Chicago, Illinois.

The subscription price to non-members of the Association is $15.00 per year (separate numbers $1.50) prepaid to addresses in the United States, Mexico, Cuba, Porto Rico, Panama Canal Zone, Republic of Panama, Dominican Republic, El Salvador, Bolivia, Colombia, Honduras, Nicaragua, Peru, Hawaiian Islands, Philippine Islands, Guam, Samoan Islands.

Postage is charged extra: For Canada, 40 cents on annual subscriptions (total $15.40), and for all other countries in the Postal Union, 70 cents on annual subscriptions (total $15.70).

Communications for the editor and manuscripts should be addressed to Raymond C. Moore, University of Kansas, Lawrence, Kan.

Requests for information concerning special rates to public and university libraries, remittances and business correspondence should be sent to Charles E. Decker, Secretary-Treasurer, 508 Chautauqua Avenue, Norman, Okla.

Correspondence regarding advertisements should be addressed to William B. Heroy, Advertising Manager, Room 1500, 45 Nassau Street, New York City.

Claims for non-receipt of preceding numbers of the Bulletin must be sent to the secretary within three months of the date of publication in order to be filled gratis.

The BULLETIN furnishes thirty-five free reprints (without covers). Additional reprints, and covers for all or part, are furnished at cost. **Orders for reprints** should accompany corrected galley proof. **Proofs and communications concerning proofs or reprints** should be addressed to Daisy Winifred Heath, Rosenwald Hall, University of Chicago, Chicago, Ill.

Back numbers of the BULLETIN can be ordered from the secretary at the following rates: Vol. I, $5.00; Vol. II, $4.00; Vol. III, $5.00; Vol. IV, $7.50, separate numbers, each $3.00; Vols. V and VI, each $10.00; Vols. VII and VIII, cloth bound, each $11.50; separate numbers, each $2.00, except Vol. V, No. 2, $3.50; Vol. 9, $15.00, numbers 1, 2, and 3, each $3.00, numbers 4 to 9, inclusive, each $1.50.

Entered as second-class matter November 21, 1925, at the post-office at Chicago, Ill., under the Act of March 3, 1870. Acceptance for mailing at special rate of postage provided for in section 1103, Act of October 3, 1917, authorized March 9, 1923.

PRINTED IN THE U.S.A.

UNEXCELLED SERVICE—
WHY?—
BECAUSE—

The sucker rod with a Whitworth Thread means less fishing and more production.

Thousands of strokes a day, and each a stroke of Quality and Perfection.

Other Quality Products: D & B Pull Rods, D & B Pumps, Fritts Rod Hangers, D & B Stuffing Boxes, D & B Sucker Rod Hooks, D & B Sucker Rod Elevators and other pumping equipment.

QUALITY SERVICE PRICE

"If CONTINENTAL Sells It There Is No Better"

THE CONTINENTAL SUPPLY COMPANY

General Offices: St. Louis

Export Office: 2 Rector St., New York

London Office: 316-317 Dashwood House, Old Broad Street, London E.C. 2, England

MORE THAN 70 STORES IN THE OIL COUNTRY

CONTINENTAL

BULLETIN

of the

AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

Vol. 10 FEBRUARY 1926 No. 2

CONTENTS

Volume 10 Number 2

BULLETIN

of the

AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

FEBRUARY 1926

FAULTING IN THE ROCKY MOUNTAIN REGION

J. S. IRWIN

PRODUCERS AND REFINERS CORPORATION, DENVER, COLORADO

ABSTRACT

Reverse faults, generally of the thrust type, are of little or no importance in their direct effect on oil and gas accumulation in the known fields of the Rocky Mountain region, but close association with certain oil occurrences suggests that oil of commercial value may yet be found dependent upon thrust-fault relationships.

Structural closures effected primarily by normal faults, similar in principle to those which are productive in Texas, have only recently been given attention. Thus far all tests have been failures, but it is probable that success will yet be attained.

Normal faults, which occur characteristically in parallel and radial systems on domes and anticlines in the Cretaceous strata of the Rocky Mountain region, are normal accompaniments of the uplifts. They are confined to the uplifts and formed at the same time as the uplifts. For such features the name "epi-anticlinal fault" is suggested.

The dual rôle of faults as avenues of, and barriers to, migration and accumulation of oil and gas is discussed.

Unfaulted upfolds are rare and abnormal. Usually apparent absence of faulting is to be ascribed either to insufficient or incompetent observation, to absence of resistant strata in shale outcrops, or to burial beneath surface deposits.

Unfaulted structures are to be regarded, generally, with less favor than faulted ones, the chances apparently being somewhat greater that the former will be barren or will carry gas largely to the exclusion of oil. Increase in depth of a given horizon by its tendency to cause tightness of fault planes and fissures tends toward the same effect as lack of faulting.

The purpose of this paper is to describe some of the various types of fault structures of the Rocky Mountain region, with special reference to their effect on migration and accumulation of oil and gas.

REVERSE FAULTS

Reverse faulting in the Rocky Mountain region is of little or no importance in its direct effect on oil and gas accumulation in the known fields. Reverse faults, generally of the thrust type, are, how-

ever, closely associated with certain oil occurrences and prospects, and it is not unlikely that oil of commercial value may yet be found which is dependent in one way or another upon thrust-fault relationships.

The locations of the general areas of thrust faulting are well known. Most of them are shown on a structural sketch map by W. T. Thom, Jr.[1] They may be recalled as follows: (1) The overthrust of the Canadian Front Range in western Alberta and its southern continuation, as the Lewis overthrust in northwestern Montana; (2) the Phillipsburg and Lombard thrust faults of western Montana; (3) the Bannock thrust fault of southeastern Idaho and northern Utah; (4) the Absaroka, Darby, and Heart Mountain overthrusts of western Wyoming; (5) the Uinta thrust fault of northeastern Utah and northwestern Colorado.

To these may be added the reverse fault along the west flank of St. Mary's anticline in Carbon County, Wyoming, the Sheep Mountain thrust fault west of Laramie in Albany County, Wyoming, and the thrust fault of the Rocky Mountain Front Range at the town of Golden, Jefferson County, Colorado. The great fault at the east end of the Ferris Mountains and west end of the Seminoe Mountains, Carbon County, Wyoming, is also apparently of the thrust type. Certain of these thrust faults which have actual or potential connection with oil occurrences will be further considered.

Canadian Front Range overthrust.—The Canadian Front Range overthrust is not associated with known oil and gas occurrence, but the zone of intense folding immediately to the east, in the foothills belt, yields a small amount of oil and gas. The proximity and parallelism of the fault and the folds indicate their common origin in a force from the west, and suggest a tendency for folds to develop in front of thrust faults. This tendency is exhibited in a number of the other areas mentioned, and is worthy of recollection in prospecting areas in front of thrust faults were buried folds may exist below flat-lying, homoclinal, or slightly deformed beds.

Bannock, Absaroka, and Darby thrust faults.—The Bannock, Absaroka, Darby, and associated thrust faults constitute a zone of

[1] W. T. Thom, Jr., "The Relation of Deep-seated Faults to the Surface Structural Features of Central Montana," *Bull. Amer. Assoc. Pet. Geol.*, Vol. 7 (1923), p. 3.

imbricated structure associated with many folds which are essentially parallel to the faults. One of these folds, the Big Piney–La Barge anticline, is of interest because of the discovery of small quantities of oil on it in four sands of the Adaville formation, which is correlated with the Mesaverde and Lower Laramie formations.[1] This fold is one developed in front of the Darby overthrust, and later has been transgressed by the overthrust mass. Cambrian and younger Paleozoic strata override latest Cretaceous and earlier Tertiary beds, hence the throw is more than 20,000 feet, and the age of the greater part of the essentially contemporaneous folding and faulting is late Cretaceous and early Tertiary, or the same as all the major diastrophism of the Rocky Mountain region. The sinuosity of the fault scarp, as mapped by Schultz,[2] and fault outliers of Paleozoics resting on the Cretaceous indicate that the inclination of the fault plane is low and that the horizontal movement has been great, probably more than 15 miles from the west toward the east. It is clear that the force which produced the overthrust and the associated anticlines could not have been applied from any other direction than the west. Here, then, we have a case of an asymmetrical fold with the steeper flank toward the direction from which the formative force is applied, for the west limb of the Big Piney anticline has maximum dips of 35 degrees, whereas the east limb has maximum dips of 25 degrees.[3]

Southwest of the Big Piney field, in the vicinity of Fossil, Wyoming, oil springs have been known since the days of the earliest emigrants. The oil springs, according to Veatch,[4] "occur in the

[1] *U. S. Geol. Survey Prof. Paper No. 56* (1907), pp. 73–75.

During the summer of 1925 a commercial oil pool was developed on the La Barge anticline, 10 miles south of the occurrence in the Adaville formation, at Big Piney. The wells in the new pool start in strata of Tertiary age and derive their production at depths of 600 to 1,000 feet from horizons in the underlying Cretaceous whose identities have not been definitely determined, but which are probably in or near the Frontier formation.

[2] A. R. Schultz, *U. S. Geol. Survey, Bull. 543* (1914), Pl. I.

[3] Max W. Ball, reference to experiments of Hobbs and others, *Amer. Assoc. Pet. Geol.*, Vol. 5 (1921), p. 60.

[4] A. C. Veatch, "Geography and Geology of a Portion of Southwestern Wyoming," *U. S. Geol. Survey Prof. Paper No. 56* (1907), pp. 157–58.

region of profound disturbance along the Absaroka fault." He states further that

> The strata around these springs, and for many feet below, belong to the Wasatch [Eocene]. These beds show a gentle anticline, with dips of about 5 degrees, and the springs occur near the axis of the anticline. . . . . The geologic relations of the adjoining areas indicate rather conclusively that this anticline corresponds very nearly in position and direction with that of the underlying Absaroka fault, and it has doubtless been produced by a slight movement along this older axis.

Obviously, fractures, or lack of impervious capping, or both causes, prevent commercial accumulation here, but the situation suggests the possibility of migration along thrust faults, which may result in commercial pools where the reservoir conditions are correct.

Uinta thrust fault.—The great thrust-fault which marks the northern face of the Uinta Mountains in northeastern Utah and northwestern Colorado is of interest because of the fact that it partly overrides a very favorable-appearing structure—the Clay Basin dome. The areal geology has been mapped by Schultz.[1] The structure, in plan and cross-section, is shown in Figure 1. The axis of the fold is approximately parallel to the generally east-west Uinta fault scarp, and the fold itself is clearly a product of the force from the south which produced the overthrust. Here, again, the flank of steeper dip is toward the south, the direction from which the thrust comes. On this limb the attitude changes gradually from horizontal at the crest of the dome to vertical near the fault, the bending being downward toward the fault. The maximum dip on the north limb is 25 degrees.

Deformation in the adjacent exposures of Wasatch (Eocene) strata, and the fact that these strata are transgressed by the overthrust mass of pre-Cambrian quartzites, indicate that both folding and faulting were, at least in part, contemporaneous, and that both movements extended far into Eocene time. The throw thus indicated is more than 30,000 feet. So far as can be inferred from the present location of the fault scarp, the horizontal movement appears to have been some four or five miles from the south toward the

[1] A. R. Schultz, "Oil Possibilities in and around Baxter Basin, etc.," *U. S. Geol. Survey Bull. 702* (1920), Pl. I.

north. These figures indicate a dip of approximately 45 degrees on the fault plane.

Clay Basin dome may be described briefly as an ovoid uplift, the south side of which has been rendered oblate by thrust forces from the south. Considering only that portion of the uplift which lies north of the zone of extremely high dips near the thrust fault, the closure is 8 miles long, 4 miles wide, and 900 feet high. The high

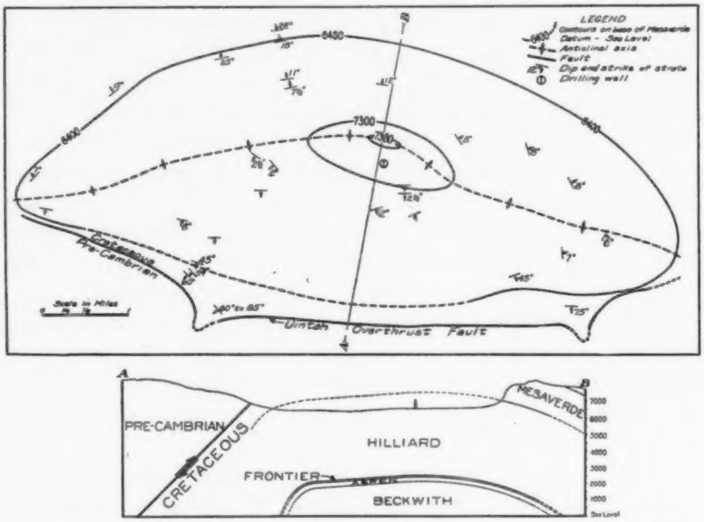


FIG. 1.—Uinta overthrust and Clay Basin Dome, Daggett County, Utah

dips near the fault, which possibly continue for an unknown distance under the hanging wall, may add greatly to the above figures. The first well is now being drilled on the fold, with the Frontier and Beckwith sands as the objectives.

It seems apparent that the Uinta thrust fault cannot have directly affected oil or gas accumulation in the Clay Basin dome. The dome has adequate folded closure, independent of the fault, and it appears that the fault, or, more properly, the force which produced it, can have had effect only in a formative way on the structure.

Golden thrust fault.—Throughout the greater part of the Rocky

Mountain Front Range in Colorado the sedimentary formations of the Great Plains bend upward in normal succession over the uplifted pre-Cambrian basement rocks. However, a notable point of departure from this simple relationship exists twelve miles west of Denver, in the vicinity of the town of Golden. Here the pre-Cambrian igneous and metamorphic rocks have been pushed eastward and upward over the upturned edges of the sedimentary rocks, which range in age from Pennsylvanian to Cretaceous. Although the existence of thrust-fault relationships at this point is now well known, it was not recognized by Emmons, Cross, and Eldridge in their monograph on the Denver basin. They attempted to explain the situation as an unconformity.[1] The structure at Golden was also incorrectly interpreted by the Colorado Geological Survey, as is reflected by their areal mapping in the vicinity.[2] Although some 9,000 feet of strata are cut out here, this is not reflected by the areal mapping, and no faulting is shown. An overlap of Tertiary beds cutting across the boundaries of formations from Cretaceous to Pennsylvanian is shown, when in fact only the upper Laramie is overlapped.

The first and only published interpretation of the structure at Golden as a thrust fault was by Ziegler, in 1917.[3] The structure of the Golden fault area is shown in partially diagrammatic cross-section in Figure 2. The profile and thickness of strata are drawn to scale.

Briefly, the probable origin of the structure is a monoclinal flexure passing into an overturned Z-fold, which, upon continuation of the thrust from below and from the west, passed into an overthrust fault or, probably more correctly, an upthrust fault. The stratigraphic throw is some 8,000 feet, and the field relationships suggest a comparatively steep dip of the fault plane—probably 55 degrees or more. The outcropping Fox Hills and Laramie beds on the downthrow are overturned 20 to 30 degrees past the vertical. The overturn is not due to drag, as the dips are too regular, the beds

[1] S. F. Emmons, Whitman Cross, and G. H. Eldridge, *U. S. Geol. Survey, Monograph 27* (1896).

[2] Geologic Map of Colorado, 1913, Colorado State Geological Survey, R. D. George, state geologist.

[3] Victor Ziegler, "Foothills Structure in the Rocky Mountains," *Journal of Geology*, Vol. 25 (1917), pp. 715–40.

too undisturbed, and the distance from the fault too great for that. Near the fault plane a mass of brecciated and distorted Niobrara limestone occurs, indicating either more than one fault, or detachment and dragging of this material upward along the main fault.

Arapahoe and Denver beds of Eocene age are met within a few hundred yards passing eastward from the fault, and these mask the structure of the Cretaceous rocks for many miles to the eastward.

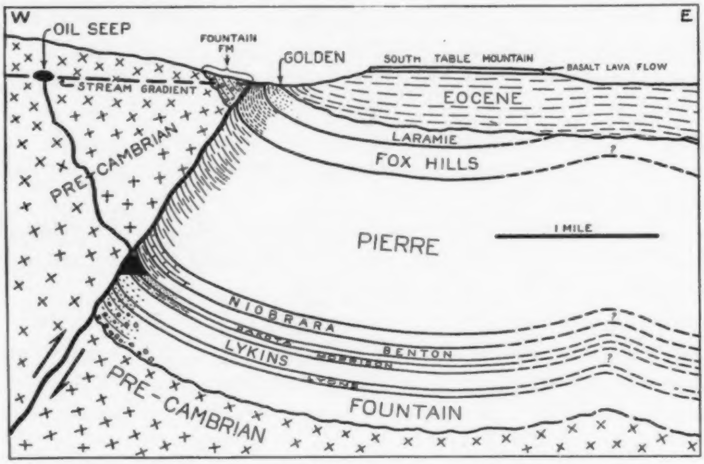


Fig. 2.—Thrust fault at Golden, Colorado. Partially diagrammatic

The attitude of the Eocene beds is generally flat to slightly eastward-dipping, with some rather meager evidence of west dip in the vicinity of South Table Mountain, two miles east of the fault.[1] It is not impossible that concealed folds may exist in front of the Golden thrust fault and beneath the Tertiary cover, similar in type to those associated with the Darby, Absaroka, and Canadian Front Range overthrusts, and that the suggestion of reverse dip at South Table Mountain is the reflection of steeper reverse dip in the buried Cretaceous.

An active oil seep in Gold Run Canyon, $1\frac{1}{2}$ miles north of Golden,

[1] Low west dips in the Eocene Denver beds in the vicinity of South Table Mountain were first recorded in a private report by F. M. Van Tuyl, December, 1924.

is an interesting accompaniment of the overthrust, and is evidently caused by the structural relationships induced by the faulting.[1] The seep is especially unique in that the oil emerges from pre-Cambrian gneiss. Apparently, the oil originates in the upturned Cretaceous beds which form the foot wall of the thrust fault, migrates upward across the fault plane, and escapes to the surface through joints in the gneiss of the hanging wall. At times enough oil collects in small depressions and on the surface of puddles of water in the generally dry creek bed so that small bottles may be filled with it. Iridescent films of oil are always in evidence when there is water standing in the depressions. Plastic asphaltic material occurs here and there, and masses of pebbles and bowlders in a matrix of dry asphalt, resembling the material of bitulithic pavement, abound. The reported occurrence of gold in the sand and gravel adds to the interest of this anomalous situation.

It is evident that the structural relationships along the plane of the Golden thrust fault are essentially the same as at an angular unconformity. Had the gneisses of the hanging wall been impervious, as they might have been expected to be, and if the thrust plane is sealed near the surface, as it may well be, a commercial oil pool might have existed beneath the overthrust. It is even possible that dissipation of the oil has been so slow that a commercial pool does exist, but if so it may be near or far from the point of present emission.

The foregoing consideration of thrust faults of the Rocky Mountain region that are at all closely associated with producing or prospective oil and gas fields leads to the conclusion that no cases are known where thrust faults have had any direct effect on oil migration and accumulation to a commercially valuable extent. It is quite conceivable, however, that where hard rocks are in juxtaposition along the thrust plane, a zone of brecciation will occur which may act as a reservoir for hydrocarbons if impervious capping be provided by the hanging wall and by either impervious younger beds laid down over the outcrop of the fault or by an area of shale along that portion of the fault plane which lies between the reservoir

[1] Mentioned by F. M. Van Tuyl in a paper on "The Rocky Mountain Front Range," read before the Rocky Mountain Association of Petroleum Geologists, 1924.

zone and the outcrop. On the other hand, if frangible strata oppose each other throughout the course of the thrust plane, a zone of porous breccia is likely to extend to the surface, thus providing an avenue of escape for liquids and gases. The remaining favorable case is where the strata in the foot wall serve as the reservoir, the hanging wall is impervious, and there is sufficient shale along the thrust plane to seal it. This latter case is essentially the situation at Golden, except that there the hanging wall is not impervious.

NORMAL FAULTS

On account of the scope of this paper, only those normal faults which are associated with known or prospective oil and gas fields will be discussed. Of these faults, certain ones fall in a very definite group. They are those minor normal faults, occurring in parallel or radial systems, which are confined to the crests and flanks of anticlines and domes of the mountain type. Since this type of fault is confined to upfolds, we may term them epi-anticlinal faults, the word "epi-anticlinal" having been suggested by Pratt to describe any feature which is on, or characteristic of, upfolds.[1]

The other type of normal fault to be discussed here includes those faults which, due to their position with respect to folds or to other faults, may be expected to form structural closure suitable for the accumulation of oil and gas. These may be referred to as fault closures.[2]

Fault closures.—Structures which depend primarily upon sealed faults for closure have thus far been given little attention in the Rocky Mountain region, although they have achieved prominence in Texas. Four recent tests on as many different fault closures, one in Colorado and three in Wyoming, have been unsuccessful, but in one of the Wyoming operations the results are not conclusive. Notwithstanding these reverses, it is highly probable that productive fault closures will be found.

Brief descriptions of the Buckeye structure in Larimer County,

[1] Wallace E. Pratt, Discussion of "Rock Distortion on Local Structures in the Oil Fields of Oklahoma by James M. Gardner," *Bull. Amer. Assoc. Pet. Geol.*, Vol. 6, No. 3 (1922), p. 243.

[2] It is, of course, possible for epi-anticlinal faults to be so arranged that they form structural closure.

Colorado, and of the Buck Springs structure in Carbon County, Wyoming, will serve as typical examples of Rocky Mountain fault closures.

Buckeye structure.—The fault closure which we may call the Buckeye structure was noted and recommended for development by F. F. Hintze, in December, 1924. At this point in the Colorado Front Range the major monoclinal flexure is intersected diagonally by a minor cross-fold which originates in the pre-Cambrian basement rocks to the northwest and pitches strongly to the southeast. At the point of intersection the monoclinal flexure breaks down into a normal fault, conceivably as a result of the concurrence of the two components of uplift. The downthrow of the fault is on the southeast, or plains, side, and since the pitch of the axis of the cross-fold and the general direction of dip of the strata is eastward, the fault, if sealed, will provide closure only for the downthrow side.

Closure along the fault toward the northeast and the southwest is provided partly by the flanks of the cross-fold and partly by a number of minor dip faults perpendicular to the major fault.

The dip of the fault plane appears to be between 75 degrees and vertical, and the data indicate a throw of something over 1,000 feet. At the points of greatest throw the base of the Niobrara formation approaches very close to the Dakota sandstone, so that not more than 100 feet of Benton shale remain between.

The most unfavorable feature associated with the Buckeye structure lies in the fact that the prospective oil sand is faulted down into juxtaposition with the Fountain formation (Pennsylvanian), which contains a number of porous members. In case the prospective oil or gas sand should be opposed to a porous member of the Fountain, migration across the fault plane might occur.

The fact that in the case of the Buckeye structure it was necessary to rely upon the downthrow side of a fault for accumulation is not in itself a valid objection, since, if a fault plane is sealed, it is immaterial whether the reservoir beds dip toward it or away from it.

Favorable considerations which led to the drilling of a test well are: (1) shallow depth, 2,000 feet; (2) proximity of commercial production, 5 miles; (3) favorable artesian conditions—sufficient static head, and improbability of artesian flushing, such as apparently ob-

tains in gently folded structures near the mountains, and as examples of which the unproductive Haystack, Berthoud, and Douglas Lake folds in Boulder and Larimer counties, Colorado, may be cited. The objective sands, the two main sand members of the

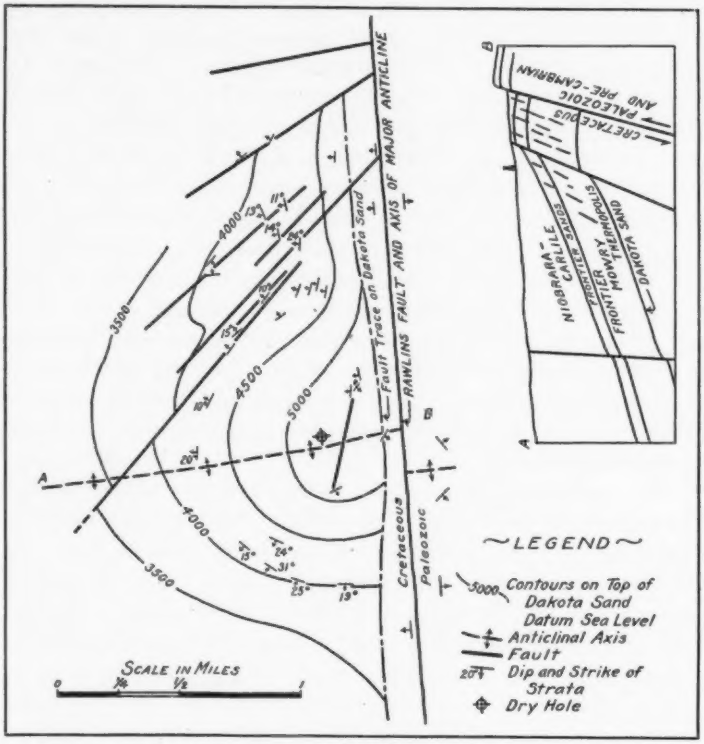


FIG. 3.—Buck Springs structure, Carbon County, Wyoming. Partially diagrammatic.

Dakota group, were found water-bearing on the Buckeye structure, and it has been abandoned.

Buck Springs structure.—The Buck Springs structure was first noted by F. F. Hintze, in September, 1922, and was mapped by him and recommended for development. The structural situation is represented in plan and section in Figure 3. The giant anticline which

forms the Rawlins Hills is split along its crest by a normal fault. The throw is greatest at the south end, near Rawlins, where Cambrian quartzite and pre-Cambrian granite are in juxtaposition with Cretaceous strata. The throw decreases northward until it dies out on Separation Flats, 15 miles to the northward. Near the north end the giant faulted anticline is traversed by a very gentle cross-fold. The intersection of this cross-fold with the fault forms what might be styled half-domes, one on either side of the fault. The half-dome on the east, or upthrow, side is in Paleozoic rocks, and offers no prospective producing horizons. The half-dome on the west, or downthrow, side is in Cretaceous rocks, with the Niobrara formation at the surface and the Dakota formation at a depth of approximately 900 feet. The downthrow is several hundred feet lower in surface elevation, and some 3,000 feet lower, structurally, than the upthrow.

Since the Dakota sandstone members (the main objectives of drilling) are faulted down against pre-Cambrian crystalline rocks, and some 900 feet of Colorado shale are involved in the fault between the Dakota sands and the surface, there seemed to be a reasonable chance that closed reservoir conditions would exist on the Buck Springs structure.

The main fault plane at Buck Springs is either vertical or dips westward at a very high angle. As might be expected, the Cretaceous beds on the downthrow near the main fault are highly deformed, upturned, and cut by a number of minor faults which trend generally in a direction diagonal to that of the main fault and to the strike of the beds. In order to avoid the zone of extreme deformation near the main fault, and to prevent drilling through the fault at depth, the location for the first well was made 1,200 feet west of the surface trace. That this was not far enough from the main fault to avoid some rather large subsidiary faults or compressed zones is attested by the fact that the interval from the top of the Frontier to the top of the Dakota, which was known to be 1,135 feet in a well four miles to the north, was here shortened to 700 feet. Intervention of faults between the test well and the drainage area to the westward may explain, at least in part, the fact that no oil or gas was found in the objective sands. These sands carried water.

Epi-anticlinal faults.—Normal faults, which occur characteristi-

cally on domes and anticlines of the mountain type in the Cretaceous strata of the Rocky Mountain region, are normal accompaniments of such upfolds. Although it is but natural that the writer's observations have been confined largely to upfolds, with much less attention paid to synclinal and interfold areas, it is his opinion that the minor fault systems which occur so frequently on upfolds are local features, largely confined to the immediate uplift, and that they are not regional in the sense held by Wegemann.[1] He assumes that the faults of the Salt Creek field, on account of their parallelism and the fact that they "appear to bear no direct relation to the shape of the fold, but cut across anticlines and synclines alike," are independent of, and subsequent to, the formation of the anticline. In seeking a regional cause for the faulting he mentions, although noting that it may be a mere coincidence, that the faults of the Salt Creek field are very nearly parallel to the larger axes of the intrusive masses in the Granite Mountains of central Wyoming, and concludes that "the movement, whenever it occurred, was probably regional rather than local." Contrary to Wegemann's view, a glance at his own map of the Salt Creek–Teapot fold[2] discloses the fact that the faults are largely confined to that fold and to the east limb of the contiguous Tisdale or Powder River dome.

Perhaps the best single piece of published evidence in favor of the local origin of epi-anticlinal faults is the geologic map of the Baxter-basin region by Schultz.[3] The coextensive nature of the uplift and the fault system is at once apparent on this map.

Other typical examples of epi-anticlinal fault systems are:

Field or Structure	Minimum Number of Faults and Their Arrangement
Montana:	
Cat Creek	50 transverse to axis
Wyoming:	
Elk Basin	26 transverse, 5 axial, 2 oblique
Garland (Fig. 4)	24 transverse, one axial

[1] C. H. Wegemann, "The Salt Creek Oil Field, Wyoming," *U. S. Geol. Survey Bull. 670* (1918), p. 27, and "Notes on the Oil Fields of Wyoming," *Amer. Assoc. Pet. Geol. Bull.*, Vol. 4, No. 1 (1920), p. 40.

[2] *U. S. Geol. Survey Bull. 670*, Pl. I.

[3] A. R. Schultz, "Oil Possibilities in and around Baxter Basin, in the Rock Springs Uplift, Sweetwater County, Wyoming," *U. S. Geol. Survey Bull. 702* (1920), Pl. I.

Field or Structure	Minimum Number of Faults and Their Arrangement
Tisdale	Several transverse (incompletely mapped)
Salt Creek	20 transverse
Teapot	
Little Lost Soldier (Fig. 5)	21 radial
Baxter Basin	50 transverse and oblique
St. Mary's	9 transverse, 5 axial
Colorado:	
Tercio Park (Fig. 6)	13 transverse and oblique
New Mexico (Fig. 7):	
Southern Ute and Barker Draw	11 transverse faults
Biltabito (Bitlabito)	14 transverse

Writing on the faults of the Salt Creek field, Estabrook[1] states that "the faults diminish rapidly in magnitude as one passes east or west [i.e., along the trend] from the point of greatest throw." In other words, the faults are local accompaniments of the uplift. This conclusion is borne out by similar conditions in all the other fields of the Rocky Mountain region where faulting of this type can be observed.

The notable parallelism of epi-anticlinal faults in a given region or district, such, for example, as the Big Horn basin and the Salt Creek–Tisdale–Teapot district of Wyoming may be explained by the fact that the majority of the epi-anticlinal faults develop transverse to the axis of the folds. Now, as the axes of the folds in the above-named region are aligned in a general northwest-southeast direction, the faults have generally northeast-southwest trends. The underlying cause of alignment of epi-anticlinal faulting in a particular district is, therefore, regional, but the evidence cited strongly suggests, if it does not prove, that the relationship between folding and faulting is genetic and, therefore, local.

Just why the apparently normal habit of epi-anticlinal fault systems should be transverse to the anticlinal axis is a fundamental question and for this the writer has no explanation. In some cases the arrangement of the faults is more or less radial, with the crest of the uplift as a center. Such an arrangement, and reasons therefor, would have been easier to conceive as the normal. The problem is apparently one of pure mechanics.

[1] E. L. Estabrook, "Faulting in Wyoming Oil Fields," *Amer. Assoc. Pet. Geol. Bull.*, Vol. 7, No. 2 (1923), p. 100.

The reason for the occurrence of epi-anticlinal faults is, at least in part, apparent. It has been noted by Willis[1] that gravity faults of normal displacement frequently occur in horizontally bedded sandstones which overlie shale beds, in consequence of the unequal subsidence of the shale, resulting from any disturbance of equilib-

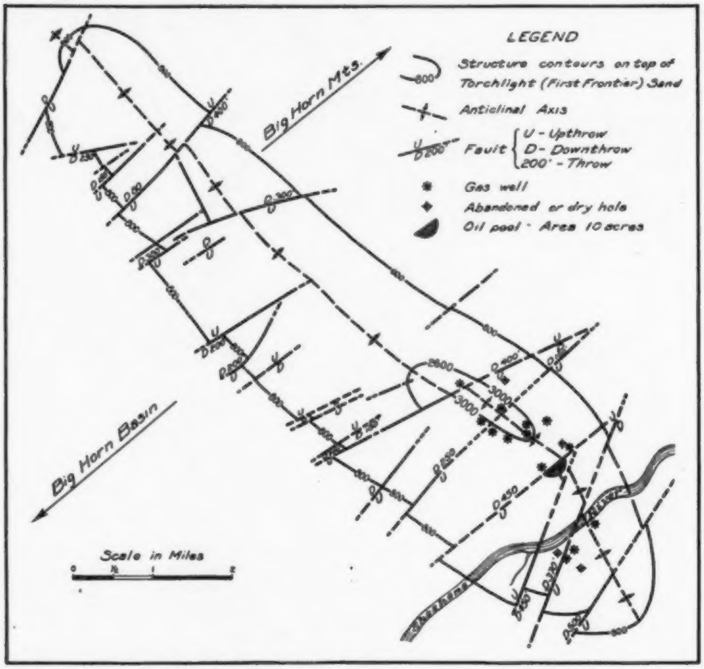


FIG. 4.—Garland anticline, Park and Big Horn counties, Wyoming

rium. Now, certainly, domes and anticlines are loci of maximum disturbance during their growth, and where the strata involved are composed of great thicknesses of shale, alternating with relatively thin competent members, the conditions are ideal for a shaking-down process which results in gravity faulting. A high proportion of incompetent, compressible material, such as shale, is the lithologic pre-

[1] Bailey Willis, *Geologic Structures* (1923), p. 68.

requisite in the process outlined, the hard members in general being of importance only as markers of the movements. When, however,

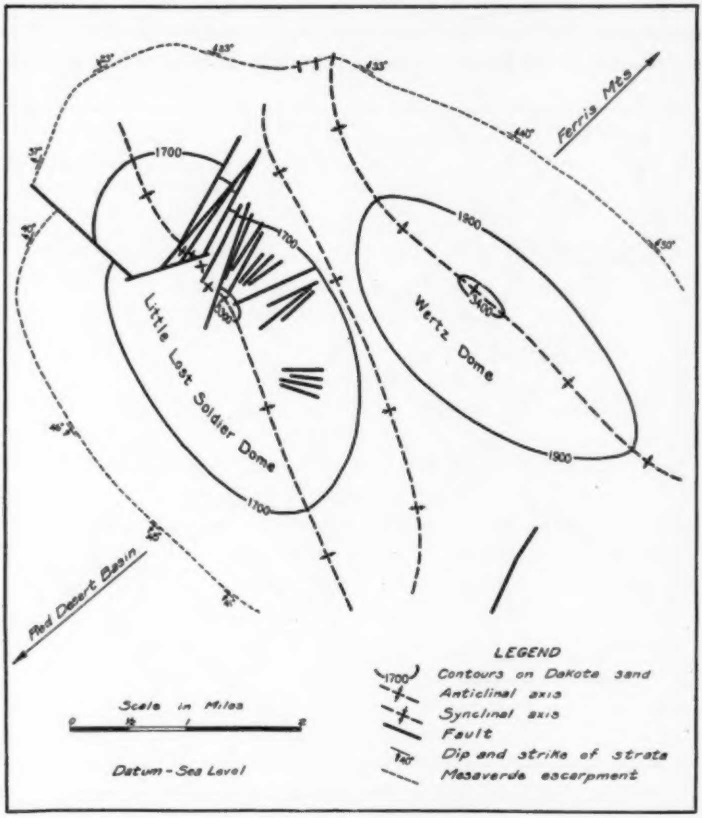


FIG. 5.—Little Lost Soldier and Wertz domes, Carbon County, Wyoming. On account of scarcity of resistant beds and extensive cover, no attempt has been made to map faults on Wertz Dome.

the hard member is porous, it becomes of practical importance as a possible reservoir for oil and gas.

It is at once apparent that the Benton, Frontier, Niobrara, and Pierre formations, with their great thicknesses of shale and included,

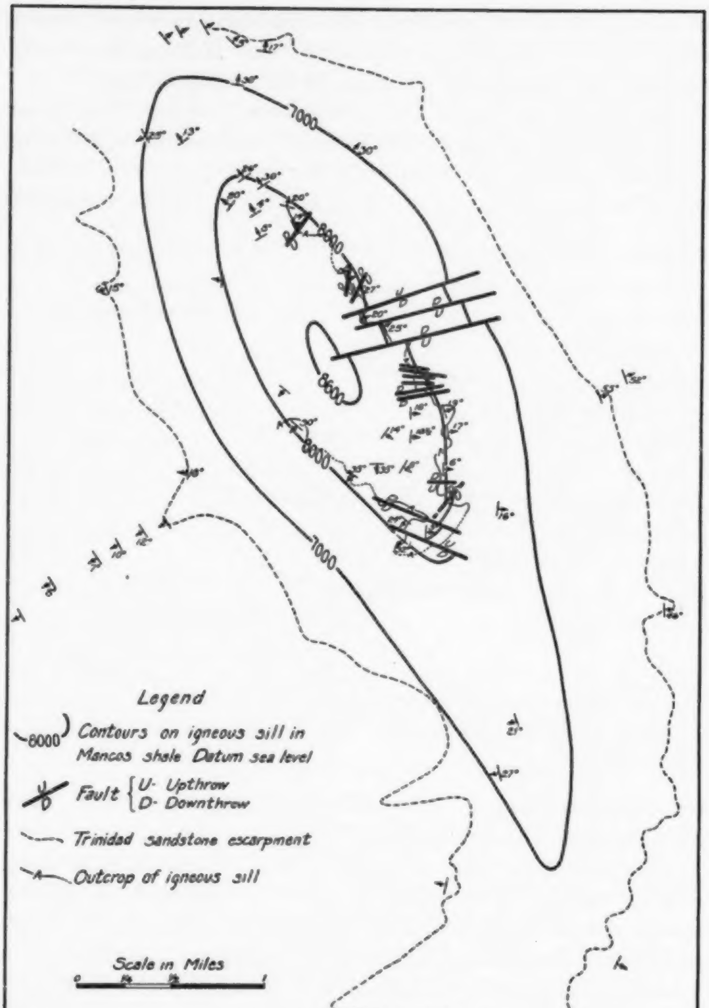


FIG. 6.—Tercio Park Dome, Las Animas County, Colorado

or closely associated, relatively thin sandstone members, furnish ideal lithologic conditions for intricate minor faulting, where they are folded into domes and anticlines of the mountain type.

As a corollary of the above proposition, it follows that minor faults of the upfold type may be expected to die out at depth as the Paleozoic section, with its steadily increasing proportion of competent strata, is approached. This condition would explain the

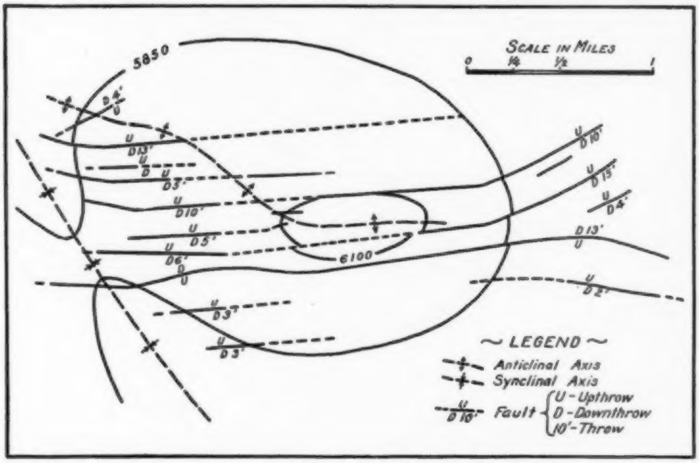


FIG. 7.—A faulted dome in northwestern New Mexico, structure contours on Navajo sandstone.

scarcity or absence of epi-anticlinal faulting on folds in older Mesozoic and in Paleozoic strata.

The mechanical effect of tension, which, at least in some cases, may be thought of as attendant upon the formation of upfolds, should not be omitted as a possible contributory cause of epi-anticlinal faulting. One example of elongation of strata involved in a fold is all that space will permit here. A section across Wertz and Little Lost Soldier domes shows an elongation in the upwarped Mesaverde sandstone of 1,000 feet in a distance of 21,000 feet—a little less than 5 per cent. If we assume that the fold is of the parallel type, and draw a cross-section on the Dakota sand 7,500 feet deeper,

we find an elongation of 2,500 feet in 15,000, or $16\frac{2}{3}$ per cent. It is not to be supposed that the resultant stretching would be anywhere near the percentages stated, due to the self-supporting effect induced by depth of burial and possibly by the moving inward of the peripheral areas under tangential forces; nevertheless it seems probable that tension is to be reckoned with as contributory to epi-anticlinal faulting.

Having given, in brief, a possible explanation for the characteristic occurrence of normal faults on upfolds, the obvious thought is: why are not all upfolds faulted which possess the requisite stratigraphic sequence postulated above? The writer would not attempt to explain away every exception to the rule, but, certainly, variable direction and rate in the application of diastrophic forces, and variable depth of burial (load) would yield variable results.

Without going deeply into statistics it may be noted that twenty-eight out of fifty-five upfolds of the Big Horn basin are known to be faulted, and it is highly probable that many not known to be faulted are in reality thus deformed, for it is significant here, as elsewhere, that the list of unfaulted structures contains many which are poorly exposed, or are in areas of shale without resistant marker beds. There are, however, undoubtedly some upfolds which, although well exposed, are apparently without faults.

If, as we have attempted to show, the faults on upfolds are, in the main, local features, dependent upon the folding for their origin, then it is highly probable that the folding and the faulting are essentially contemporaneous. That this is the case is the writer's view. It is, of course, conceivable that the folds attained some height before faulting was initiated, and it is perfectly possible for more than one period of faulting to have occurred during a gradual or an intermittent uplift, but that an anticline was completely formed and subsequently faulted seems scarcely probable.

Proceeding further on the theory that folding and faulting, although active over a long period of time, were essentially contemporaneous, then oil and gas accumulation was largely subsequent to the faulting. Separate closures on Little Lost Soldier, Garland, Elk Basin, and possibly the Cat Creek anticlines, occasioned by sealed faults, are examples, but cannot be discussed further at this

time. The advisability of testing separate fault closures is thus indicated.

Detailed measurements and descriptions of individual faults would be of great interest, but such material could easily furnish subject-matter for any number of separate papers, and cannot be attempted here. Furthermore, subsurface information from drilling in proximity to faults is so meager that discussion of the subject, except, perhaps, in such extensively drilled fields as Salt Creek and Elk Basin, may well await further development. Even in the Salt Creek field, however, it is rather the exception to find wells so spaced with respect to adjacent faults that they will precisely delimit the subterranean ramifications of those faults.

A few of the characteristics of the epi-anticlinal faults may be noted briefly, as follows:

1. The vertical displacements vary from less than 5 feet to 700 feet.

2. Faults are known to extend to depths of 3,000 feet in Salt Creek, and 1,500 to 2,000 feet at Lost Soldier. How much deeper they extend is not yet known.

3. Relatively elevated or depressed blocks bounded by parallel or converging faults are common.

4. Transverse segments of folds are often shifted along the trend of the faults which bound the segments. The movement may therefore vary from horizontal to vertical, and through any combination of the two. The most noticeable result of a horizontal component (strike-slip) in the movement is offset of the anticlinal axis in the various segments. The Garland, Baxter Basin, and Little Lost Soldier anticlines are good examples.

5. The faults are occasionally pivotal, downthrow at one end passing into upthrow at the other.

6. In some cases the faults affect the position of the oil-water contact; in others they do not.

At Little Lost Soldier, for example, on a relatively elevated fault block, oil wells have been obtained 300 feet or more lower (vertically) on the structure than at another point not directly affected by faulting. Here the boundary of the productive area is far within and above the limit of closure, and many of the faults have throws con-

siderably greater than the thickness of the productive sands. Such conditions permit the various faults and fault blocks to exert independent influences upon the position of the oil-water contact.

On the other hand, at Salt Creek the structure is filled with oil to the limit of closure, and the faults generally possess insufficient throw to separate completely the productive sands. Under such conditions the faults have little or no effect upon the position of the oil-water contact.

Effect of faults on migration and accumulation of oil and gas.—Faults have undoubtedly exercised widely variant effects on migration and accumulation of oil and gas at different periods during and after their formation, as pointed out by Lahee. They also may possess very different degrees of tightness or porosity at different points along their course, thereby permitting migration at one point and preventing it at another. Variation in the hardness of the opposing rock masses along the fault would be sufficient reason for variable permeability.

In connection with the time element it is to be remembered that in the early history of any folding and faulting many hundreds of feet of strata were involved that are now removed by erosion. The deeper the burial and the longer the fault plane, the better and more numerous are the chances that the fault has functioned as a barrier to migration of fluids. It is also conceivable that a fault or fissure is most permeable at the time of formation, and that it becomes less permeable with age, due to continued deposition of mineral matter. Pre-erosional depths are, therefore, effective at the time they are most needed.

Whenever erosion reaches a point in a fault which has an open connection with an oil or gas pool, drainage of the pool begins. Gas, if present, is likely to be drawn off first, and oil later. Or the condition may be such that gas, but little or no oil, will escape. Such a situation is illustrated by a fault on Garland dome (Fig. 4). A gas vent near this fault which could be ignited and burned with a flame 6 feet high was shown to C. A. Fisher by an old inhabitant twenty-two years ago. Later this occurrence led to the drilling of a well which discovered high-grade oil in the Torchlight sand of the Frontier formation at a depth between 500 and 600 feet. Nine wells,

very close together on an area limited to ten acres by surrounding dry holes, have developed a small but very persistent production. The production, maintained for a period of over fourteen years, to date aggregates several hundred thousand barrels. Decline curves of these wells, drawn by Fisher, indicate an ultimate recovery of 1,776,000 barrels, or 177,600 barrels per acre. Since the Torchlight sand is 35 feet thick, and assuming 15 per cent porosity, the capacity of the sand can be only 40,730 barrels per acre—a figure which production to date has already considerably exceeded. Continued accession of oil through the faults is the only apparent explanation of the situation. The wells are on a relatively elevated block, which is a separate closure formed by the convergence of two faults. This is the only oil production on the dome, the remainder of the wells being gas. Gas occurs in separate fault closures on the dome—200 feet higher than the oil in some cases; 600 feet lower in others. Here we have, within a few hundred feet of each other, faults acting as avenues for migration, accumulation, and escape in the one case, and as barriers to migration and escape in the others.

In the highly faulted Little Lost Soldier field erosion has proceeded to within 240 feet of the First Frontier sand, yet an oil pool 160 acres in extent exists in this sand. The next-lower productive horizon, the Mowry formation, lies 900 feet deeper, and the pool in it covers 680 acres. Three hundred feet below the Mowry lies the Dakota sand. The area of the pool in this sand is estimated by E. W. Krampert at 1,500 acres. These facts suggest communication between sands through faults, and are proved by the behavior of certain wells. Krampert states that a shallow Frontier sand well which was making 80 per cent water increased its oil production, and the water decreased to 10 per cent, when wells in the Dakota sand, 1,200 feet deeper, were shut in during a curtailment of production in 1921.

Of the four productive domes in the Lost Soldier district, Little Soldier dome is the only one on which the Frontier sands carry commercial production. This situation appears to be explained by the fact that Little Lost Soldier dome is very highly faulted, and the oil sands are so near the surface that all gas has escaped through the faults, while oil has migrated from below to its present position through these faults. On the other hand, the contiguous Wertz dome

is apparently much less faulted, and corresponding sands are buried 2,000 feet deeper. Faults, therefore, have probably never functioned as avenues of escape on this dome. The result is that the Dakota sand yields gas only, and the Frontier sands carry water. Mahoney dome, the next structure east of Wertz dome, is somewhat faulted, and the Dakota sand is at the intermediate depth of 2,160 feet. The Dakota sand carries gas and a rather insignificant ring of oil outside of the gas. The Frontier sands carry water and some gas, but not in commercial quantity. Evidently there has been some migration, but, due to lack of open faults, not to the extent necessary to exhaust the gas and induce the accumulation of oil.

Still farther east, Ferris dome is not known to be faulted, but the exposures are so poor that the status of faulting cannot be determined at the surface. The Frontier sands are water-bearing; the Mowry and Muddy sands, all thin and probably discontinuous, yield commercial oil; and the Dakota sand carries gas surrounded by a ring of oil—both in commercial quantity. Reasoning in a reverse direction from that above, that is, from result back to cause, it follows that Ferris dome is but little, if any, faulted.

Evidence at hand points strongly toward the validity of the following conclusions:

1. Water in an upper sand is certainly not an indication that lower sands will be unproductive. It may mean that other sands intervene between the upper sand and the source bed, and that either the structure is unfaulted or, if faulted, the faults are so tight that they do not permit migration of oil or gas to expel the water from the water sand. Teapot, Grass Creek, Enos Creek, Sand Draw, Wertz, Ferris, and Simpson Ridge structures are examples of this condition, where the first sand is water-bearing and lower sands are productive.

2. If an upper sand is primarily a gas sand, then gas, rather than oil, is the product to be expected in the lower sands of that structure. The reason for this is that, naturally, the same genetic conditions apply on any one structure, while if a structure is sufficiently tight to retain a gas pool in an upper sand, it will be even more effective in this capacity so far as deeper sands are concerned.

It is conceivable, of course, that a fault might be so open in its lower reaches and so tight nearer the surface that gas might migrate

to an upper sand, leaving oil in a lower sand. Such occurrences are, however, not common, if they occur at all. On the other hand, there are many examples of "gas only" structures possessing more than one producing sand, some of which may be listed:

Field	Number of Gas Sands
Oregon Basin, Wyoming	Two
Baxter Basin, Wyoming	Two
Garland, Wyoming	Three (oil local and anomalous)
Enos Creek, Wyoming	Two
Mahoney, Wyoming	Two
Sand Draw, Wyoming	Two
Poison Spider, Wyoming	Two
Bow Island, Alberta	Two
Viking, Alberta	Two

The above generalization may not stand, but it has been true in enough cases to make it of value as a probability in estimating gas reserves. It does not apply, of course, to the pre-Mesozoic strata, which yield heavy oil and no gas in the Rocky Mountain region.

3. Unfaulted or slightly faulted structures are likely to be either gas-bearing or barren, as has been noted by Harrison.[1] Comparatively deeper burial of sands, by its tendency to cause tightness of faults, may have the same effect as lack of faulting.

Examples of lower structures contiguous to higher structures in which the higher is primarily oil-bearing and the lower is totally or in part gas-bearing in the same sands, are:

Oil Field	Adjacent Gas Field	Gas Field Structurally Lower (Feet)
Salt Creek	Teapot (gas and oil)	1,000
Little Lost Soldier	Wertz	1,900
Grass Creek	Little Buffalo Basin	200
	Little Grass Creek	1,200
	Enos Creek	800

Attempts have been made to explain the occurrence of oil in one closure and gas in a contiguous lower closure as due to differences in the situation of these closures with respect to major structural features, such, for instance, as one of the pair being basinward and the other mountainward. Or, again, difference of position with respect to incoming oil and gas, if accumulation is in process, or to depletion

[1] T. S. Harrison, "Oil Accumulation in the Rocky Mountain Region," *Amer. Assoc. Pet. Geol. Bull.*, Vol. 7 (1923), p. 667.

of these products if flushing is dominant, has been called upon for a possible explanation of the occurrence of oil in one and gas in the other. In the cases tabulated in the preceding paragraph differences in location with respect to adjacent major uplifts and basins could scarcely have operated to cause difference in products, since none except Enos Creek anticline is completely shut off by another from the major basins, whence its supply of hydrocarbons is supposed to have been derived. Nor does a hypothesis which suggests spilling of oil from the lower to a higher structure due to crowding out of oil by gas fit the present situation, since in two of the three groups of structures, namely, Little Lost Soldier group and Grass Creek group, the various closures are far from being filled to the limits of closure.

Conditions might be imagined under which these closures might have been filled with oil or gas in their earlier history, that spilling from one to another then occurred, and that later depletion through natural causes reduced the size of the pools, but this leads us too far into the bailiwick of conjecture.

So far as the writer is aware, the evidence now available is quite insufficient to account fully for gas only in one closure, and oil only in another immediately adjacent, where the structural relationships, productive horizons, and age of folding are exactly the same. But since difference in depth of burial, as tabulated, and the effect of these differences upon openness or tightness of faults is the only obvious difference at all, it would seem that very great importance should be attached to this feature.

Comparative data concerning apparently unfaulted, unproductive structures and faulted productive ones would be interesting, but it might be difficult to prove that the difference in productiveness is due solely to the contrast in faulting. In Wyoming few, if any, anticlines can be positively said to be unfaulted, and usually structural, stratigraphic, and artesian conditions and adequacy of testing, one or the other, are either known to be at fault or are to be strongly suspected of being the reason for unproductiveness. Further discussion of this subject should be based upon detailed information from the entire region, whereas the writer's first-hand knowledge, and development to date, apply more particularly to Wyoming.

MIOCENE PALEOGEOGRAPHY IN THE CENTRAL COAST RANGES

R. D. REED
Palo Alto, California

ABSTRACT

Because of the conspicuous failure of workers in the California Tertiary to agree upon the deductions to be drawn as to the physiographic conditions that probably accompanied the deposition of the Miocene siliceous shale, it has seemed worth while to assemble the available physical and biological data that appear to have a bearing on the problem. The paper is practically an abstract of these data. The indications with reference to temperature and depth of water are not entirely consistent, perhaps because both conditions varied at different times. To the hypothesis of a Miocene desert, however, the data clearly agree in bringing no support. Peneplaned land areas, rather than rainless deserts, are considered to be the probable cause of the scarcity of clastic material in the Monterey shale and similar formations.

The beginning of the Miocene in the California region was a period of very violent crustal movement and great change of climate. A land mass to the west of the present coast line appears to have arisen and all but shut off a great inland sea dotted here and there with islands. . . . . The climate became increasingly arid later in the Miocene so that less and less sediment was washed from the lands into the quiet waters.

The foregoing passage from Gaylord and Hanna's recent paper in the *Bulletin* (1) serves to recall the fact that many phases of Miocene paleogeography are still matters of disagreement. With reference to climate, not only Gaylord and Hanna, but also F. M. Anderson (2), Jordan and Gilbert (3), and Woodford (4), have favored aridity, an important reason in each case being the difficulty of accounting in any other way for the scarcity of land-derived material in the organic shale deposits. J. P. Smith (5), Merriam (6, 7), and Chaney (8) believe, on the other hand, that the fossils of middle and upper Miocene strata prove the climate of the California region to have been more humid in Miocene time than it is at present. With regard to the scarcity of terrigenous sediment, moreover, Fairbanks (9), Arnold and Anderson (10, 11), R. W. Pack (12), and the present writer (13) have suggested that the lands, in certain areas at least, were so largely peneplaned and submerged as to con-

tribute but little detritus to the seas. Arnold Heim (14) prefers the hypothesis of deep-sea conditions, and holds (14*a*) that the climate may have been cool.

In view of the uncertainty and disagreement that exist in these and kindred matters, and of the immense economic and scientific importance of the Miocene sedimentary formations in the Coast Ranges, it may be worth while to set forth the more important available data that bear on the problems of middle and upper Miocene paleogeography. The references accompanying this paper should enable those who are interested to start pleasantly on a more comprehensive study of the subject than is here attempted.

Figure 1 shows the Tertiary formations of five areas, scattered over that portion of California in which are located the important organic shale deposits. The suggested correlations are subject to even more uncertainty than the figure suggests, but are believed to represent fairly well the consensus of present opinion.

The data to be presented are of several kinds: organic, including the evidence of the foraminifera, mollusks, fishes, mammals, diatoms, and land plants; petrologic; and structural.

The foraminifera of the basal Monterey shale of San Luis Obispo County were studied by Bagg (18). He holds that they are chiefly shallow water forms, and "were presumably deposited in waters the depth of which was less than 500 fathoms." A more recent study of much more abundant material has been made by Cushman, who has kindly furnished (19) the data here summarized. He shows that the water must have been fairly deep, since many of the forms are not found in very shallow water, at least unless the water is cool. ***Bolivina decussata*** H. B. Brady, which occurs in the Monterey shale, has also been collected in the Pacific Ocean at depths ranging from 140 to 1,800 fathoms, and temperatures below 34 degrees Fahrenheit. Species of ***Uvigerina*** similar to those found in the Monterey occur chiefly between 500 and 1,500 fathoms, in temperatures that will average about 40 degrees F. In shallow-water samples these species are either very scarce or entirely wanting. They never occur abundantly close to shore. The abundance of pelagic ***Globigerina*** indicates free access to the open ocean. With regard to temperature, Cushman concludes:

There are, we may very decidedly say, none of the species or genera which ordinarily characterize tropical or very warm water conditions. . . . . As to salinity, I see nothing to indicate any decided departure from ordinary conditions, such as obtain in the present ocean at the depths and temperatures given.

In general, foraminifera occur most abundantly in the lower part of the Monterey shale.

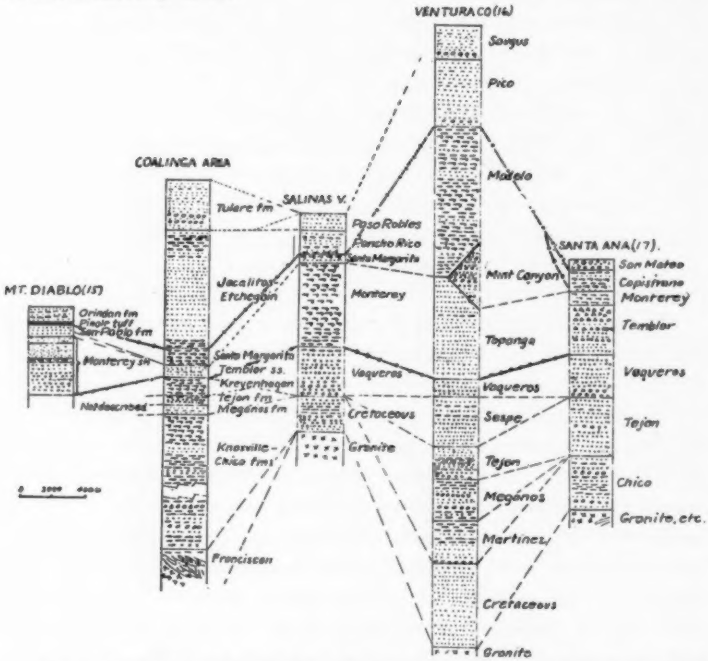


FIG. 1.—Distribution of organic shale in Mesozoic and Cenozoic formations of five areas in California. The heavy line incloses Middle and Upper Miocene formations. Symbol for organic shale, ¬ ¬ ¬.

The mollusks of the central California Miocene have been shown by J. P. Smith (20) to be most closely related to modern subtropical or tropical forms. From this fact it would seem likely that the shallow seas and lower lands were warm.

The fossil fishes of the Monterey shale are said by Jordan and Gilbert (21) to be shore forms and types that live in shallow bays.

Mammalian remains have been described from several areas in the central Coast Ranges or near enough to that region to be of interest in the present connection. In the Tehachapi Pass district, Buwalda (22) found bones of land mammals associated with palm leaves in beds that he considers fanglomerates and playa deposits of a semi-arid to arid region. The forms are middle Miocene in age. From the upper Miocene Barstow beds of the Mohave desert, Merriam has described a large number of mammals some of which were associated with lake beds containing freshwater mollusks. Merriam believes (7, p. 450) that in this area the upper Miocene was distinctly more humid than the present. Similar forms have been described, also by Merriam (23), from Miocene beds near Bakersfield, and by Stock (24), from the Mint Canyon Miocene formation of Los Angeles County. The latter, like the Barstow fossils, were associated with freshwater mollusks of lacustrine types. In the Coalinga district, finally, in Temblor strata which contain some diatomite, and which lie between formations that contain much more diatomaceous material in this general region, a notable assemblage of mammalian remains has been secured. According to Merriam (6, p. 6), it indicates that the surrounding lands were in part grassy plains supporting large numbers of grazing animals. On the whole, then, the evidence of the mammalian fossils can hardly be said to furnish strong support to the hypothesis of a rainless desert.

The diatoms, which abound in the upper part of the Monterey shale and in some Santa Margarita outcrops, have been studied by Dr. Albert Mann (25) and by Sir Nicholas Yermoloff (26). The former finds that the forms from some Lompoc upper Monterey samples are heavy bottom-dwellers, that they lived in marine bays, probably shallow, and that the tests accumulated without much preliminary drifting by currents. Yermoloff states that the Lompoc diatoms are northern forms, somewhat like those now living in European waters, whereas samples from the Los Angeles region contain more southern forms. He does not discuss the ecologic problems.

Remains of land plants are found in several places both in middle and upper Miocene strata. An upper Miocene flora from the Mount Diablo region (15, p. 52, etc.), contains *Laurus*, *Magnolia*, and other genera which, in the opinion of J. P. Smith (27), must have de-

manded 40 inches of rainfall—considerably more than the region now receives. In the same area, undescribed leaves are common also in beds considered middle Miocene in age. In probable Temblor strata of the Bakersfield region there are numerous leaves, some of them identified by F. M. Anderson (2) as sycamore, fig, and willow. In the Salinas Valley, leaves of broad-leaved trees occur in the Monterey shale itself (28). In the El Modena region near Santa Ana in southern California, finally, a very interesting assemblage of about eighteen land plants has been found in the Monterey shale. According to Chaney (6, p. 91), the trees represented suggest moist coastal swamps and river borders.

It may be noted that in none of the middle Miocene occurrences is silicified wood stated to be a prominent feature, as it is in many ancient and modern desert formations (29, 30, 31), and even in later Tertiary strata in California (11, p. 107, etc.). On the whole, then, the ecologic implications of the land plants agree with those of the land mammals. Instead of extreme aridity they suggest a moderately humid climate.

The petrologic evidence may be summarized very briefly. Ripple-marked diatomite has been found in the Monterey formation of the Huasna area by Tolman and his students (32). Most of the coarser facies of the Miocene formations are composed of poorly sorted, angular, feldspathic material, with many amphiboles among the heavy minerals. In all these respects they do not differ appreciably from Pliocene rocks; and only in the climatically unimportant presence of Franciscan heavy minerals do they differ from Eocene and Cretaceous rocks. Red beds, considered by some geologists to denote aridity, though present in certain lower Miocene or older formations, are absent or very subordinate in the middle and upper Miocene. Gypsum, salt, eolian sand, and dust, all of which are abundant in the deposits of modern seas surrounded by rainless lands (33, 34), are either absent or very scarce in middle and upper Miocene strata. In short, aside from the organic shale itself, not a single petrologic feature of any of these formations known to me suggests a lesser degree of humidity than existed during the rest of Tertiary time (4, note).

If the lands were not unusually arid, and the seas were not every-

where deep, as the preceding paragraphs tend to show, how shall we account for the scarcity of clastic material in the Monterey and other organic shale deposits? In several instances, enumerated above, geologists who had just completed detailed investigations of areas in which organic shale formations occur have expressed the view that these formations accumulated at a time when the land areas were peneplaned and largely submerged. The nature of the evidence may be illustrated from conditions in the Coalinga district. The Kreyenhagen organic shale, for example, is at the top of the following series: (*a*) Tejon pebbly sandstone, becoming finer upward; (*b*) clay shale with many foraminifera, apparently grading upward into organic shale. Beneath the Santa Margarita siliceous shale along Reef Ridge the conditions are similar. The latter formation, in addition, overlaps all the older formations and rests upon them with a very scant development of pebbly sandstone at the base. The facts suggest base-leveled lands at the margin of the sea. That the conditions here described are fairly general in areas that have deposits of organic shale, moreover, will be evident from a reading of the literature previously cited (9, 10, 12).

The fact that organic shale deposits are not limited to a single period, but range in age from upper Cretaceous at least to upper Miocene (Fig. 1), seems to agree with the hypothesis here favored rather than with the desert hypothesis. Recurrent peneplanation is usual; recurrent deserts should have left some trace of their existence.

In the hope of bringing out further discussion this brief summary of the evidence may be closed with statements of some tentative conclusions:

1. With regard to temperature, the various types of evidence seem to be in conflict.

2. The seas were probably in large part shallow, but the existence of deeps is indicated by the character of the foraminifera. It is probable that the water was deeper in early Monterey time than later (foraminifera vs. diatoms, leaves, etc.).

3. The average humidity was probably higher than that which prevails at present; it was almost certainly not less than that which prevailed during the greater part of earlier and later Tertiary time;

there seems to be no evidence in favor of the view that any considerable part of the land was so rainless as to prevent the transportation of detritus to the seas.

4. The lack of terrigeneous material in the various deposits of organic shale is probably due chiefly to the fact, of which there is much independent evidence, that the lands adjacent to the seas in which it accumulated were low.

REFERENCES

1. E. G. Gaylord and G. D. Hanna, "Correlation of Organic Shales in the Southern End of the San Joaquin Valley, California," *Bull. Amer. Assoc. Pet. Geol.*, Vol. 9 (1925), p. 231.

2. F. M. Anderson, "Neocene Deposits of Kern River," *Calif. Acad. Sci. Proc.*, 4th ser., Vol. 4, p. 111.

For a later, less positive statement, see note contributed by Anderson to (3), p. 14.

3. D. S. Jordan and J. Z. Gilbert, "Fossil Fishes of the (Miocene) Monterey Formations of Southern California," *Leland Stanford Junior University Publications*, University Series, p. 13.

4. A. O. Woodford, "The San Onofre Breccia, Its Nature and Origin," *Univ. Calif. Pub. Geol.*, Vol. 15, No. 7 (1925), p. 238.

Woodford believes that the breccia, which is interbedded with Monterey shale, implies transportation under arid conditions.

5. J. P. Smith, "Ancient Climates of the West Coast," *Pop. Sci. Mo.* (1910), p. 485.

6. J. C. Merriam, "Tertiary Mammalian Faunas of the Mohave Desert," *Univ. Calif. Pub. Geol.*, Vol. 11 (1919), p. 450.

7. J. C. Merriam, "Tertiary Vertebrate Faunas of the North Coalinga Region of California," *Trans. Amer. Phil. Soc.*, n. s., Vol. 22, Part 3 (1915), pp. 6, 23, etc.

8. R. W. Chaney, "A Fossil Flora from the Puente Formation of the Monterey Group," *Amer. Jour. Sci.*, 5th ser., Vol. 2 (1922), pp. 90–92.

9. H. W. Fairbanks, *San Luis Folio*, No. 101, p. 9.

10. Ralph Arnold and Robert Anderson, "The Santa Maria Oil District," *U. S. Geol. Surv. Bull. 322* (1907), pp. 67, 68.

11. Ralph Arnold and Robert Anderson, "The Geology and Oil Resources of the Coalinga District," *U. S. Geol. Surv. Bull. 398* (1910), pp. 172, 174, etc.

12. R. W. Pack, "The Sunset-Midway Oil Field," *U. S. Geol. Surv. Prof. Paper 116* (1920), p. 37.

13. R. D. Reed, "The Post-Monterey Disturbance in the Salinas Valley," *Journal of Geology*, Vol. 33 (1925), p. 604.

14. Arnold Heim, "Notes on the Tertiary of Southern California," *Geol. Mag.* (1922), p. 539.

14*a*. A. Heim, "Über submarine Denudation und chemische Sedimente," *Geol. Rundschau* (1924), pp. 1–47, sec. 16.

15. B. L. Clark, "The Neocene Section at Kirker Pass on the North Side of Mount Diablo," *Univ. Calif. Pub. Geol.*, Vol. 7 (1921), pp. 47 ff.

16. W. S. W. Kew, "Geology and Oil Resources of a Part of Los Angeles and Ventura Counties, California," *U. S. Geol. Surv. Bull. 753* (1924), Plate III, etc.

17. A. O. Woodford, *op. cit.*, p. 169.

18. R. M. Bagg, "Miocene Foraminifera from the Miocene Shale of California," *U. S. Geol. Surv. Bull. 268* (1905), p. 12.

19. J. A. Cushman, personal letter dated September 10, 1925.

20. J. P. Smith, "Climatic Relations of the Tertiary and Quaternary Faunas of the California Region," *Proc. Calif. Acad. Sci.*, 4th ser., Vol. 9, No. 4 (1919), pp. 123–73, Plate IX.

21. D. S. Jordan and J. Z. Gilbert, "The Fossil Fishes of the Diatom Beds of Lompoc, California," *Leland Stanford Junior University Publications*, Univ. Ser. (1920), p. 6.

22. J. P. Buwalda, "New Mammalian Faunas from Miocene Sediments near Tehachapi Pass, in the Southern Sierra Nevada," *Univ. Calif. Pub. Geol.*, Vol. 11 (1916), pp. 75–85.

23. J. C. Merriam, "Remains of Land Mammals from Marine Tertiary Beds in the Tejon Hills, California," *Univ. Calif. Pub. Geol.*, Vol. 8 (1915), pp. 283–88.

24. Chester Stock, in Kew, *op. cit.*, p. 54.

25. Albert Mann, in (21), p. 6.

26. Sir Nicholas Yermoloff, "The Diatomaceous Earth of Lompoc, Santa Barbara County, California," *Geol. Mag.* (1920), p. 273.

27. J. P. Smith, oral communication.

28. Specimens collected, 1925, by Eric K. Jordan.

29. Chudeau and Fritel, "Bois silicifiés du Sahara," *Bull. Geol. Soc. France* (1920), pp. 202–7.

30. E. H. Pascoe, "Oil Fields of Burma," *Mem. Geol. Survey India*, Vol. 40 (1912), p. 41.

31. H. G. Lyons, "On the Stratigraphy and Physiography of the Libyan Desert of Egypt," *Quart. Jour. Geol. Soc.*, Vol. 50 (1894), p. 545.

32. C. F. Tolman, oral communication.

33. Johannes Walther, *Das Gesetz der Wüstenbildung*, vierte Auflage, Leipzig (1924), esp. Abb. 123.

34. Karl Andrée, *Geologie des Meeresbodens*, Vol. II, Leipzig (1920), pp. 181, 194, 540–42, etc. (Description of sediments of Red Sea and Persian Gulf.)

BURIED HILLS NEAR MANNSVILLE, OKLAHOMA

C. W. TOMLINSON
Ardmore, Oklahoma

In Secs. 34 and 35, T. 4 S., R. 4 E., Marshall County, Oklahoma, about 7 miles northwest of Madill, there is a group of outcrops of pre-Pennsylvanian rocks (Fig. 1), which have not heretofore been described in print. They occur 3 or 4 miles south of the northern limit of the Gulf coastal plain, as marked by the north edge of the Trinity sand. Being difficult of access, they were easily overlooked in the mapping of the Tishomingo quadrangle 25 years ago.

STRATIGRAPHY

The accompanying detail map (Fig. 2) shows the exact distribution of these exposures, which include an outcrop of Sycamore limestone, four outcrops of the Woodford chert, four of the Hunton formation, and three of the Viola limestone. The Viola outcrops are the most extensive, covering an irregular area totalling about 2 acres. All of these outcrops occur in the bed and lower walls of deep ravines occupied by Turkey Creek and its tributaries, which have cut through the overlying formation (Fig. 3). Both above and below these exposures, beds of the Trinity formation extend to topographic levels lower than the surface of the Paleozoic outcrops. This is not, in the main, a result of folding of the Trinity beds, but rather of a thickening of the lowermost member of the Trinity on either side of the lower outcrops. Thus it is evident that these outcrops represent buried hills beneath the Trinity, constituting a part of the pre-Comanchean surface of erosion. There is, however, a slight arching of the Comanchean beds over this general neighborhood.

A detailed description of the Paleozoic rocks exposed here follows:

Sycamore limestone.—The single exposure of the Sycamore limestone found in this area shows the following members:

Feet
45 Dense drab massive blocky limestone, very finely crystalline, in beds 2 inches to 1 foot thick. No fossils found
35 Concealed interval
9 Limestone like that above
3 Concealed interval
10 Dense drab blocky limestone, very finely crystalline. No fossils found
2 Greenish calcareous shale
1 White calcareous sandstone, medium coarse-grained

FIG. 1

Woodford chert.—The southernmost outcrops consist of striped black and white chert, pretty well rotted and much iron stained, overlain by a 10-foot bluff of massive chalky limestone of the Trinity formation containing many angular fragments of chert. The basal 2 feet of the limestone grades into recemented subsoil on the Devonian rocks, which still shows interrupted steeply-dipping

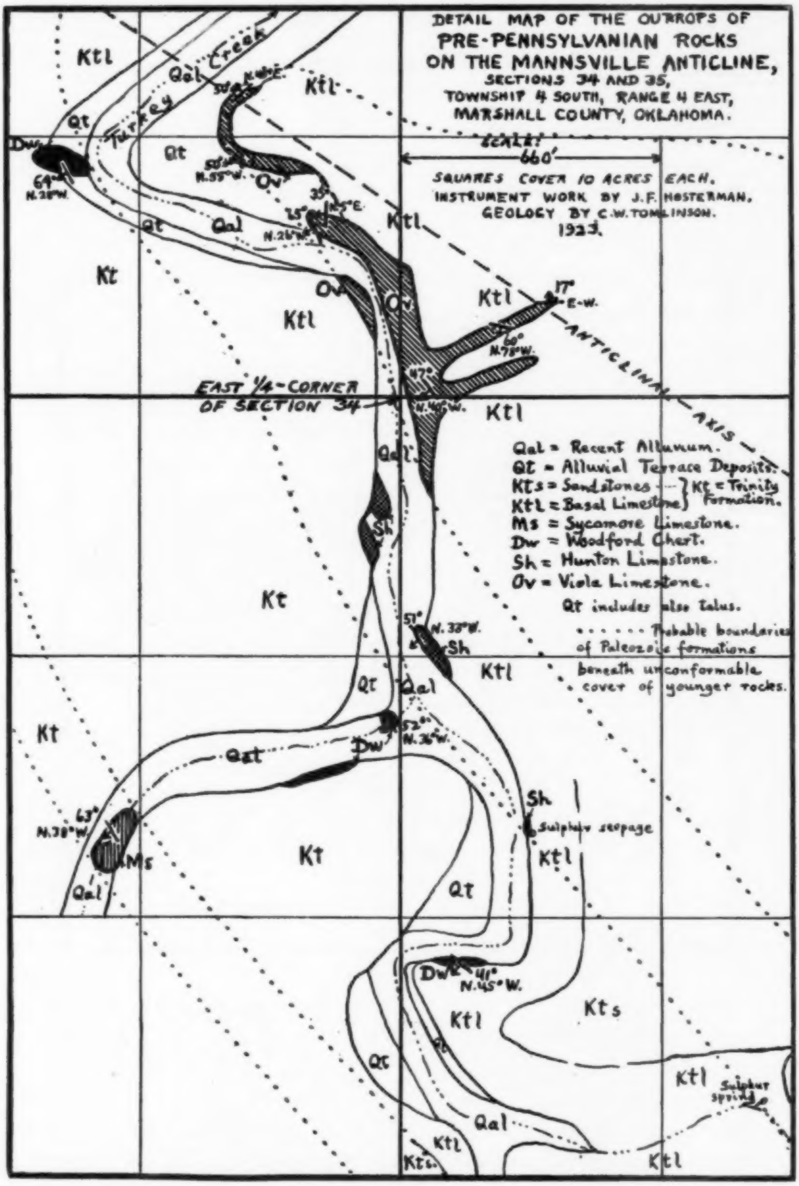

DETAIL MAP OF THE OUTROPS OF
PRE-PENNSYLVANIAN ROCKS
ON THE MANNSVILLE ANTICLINE,
SECTIONS 34 AND 35,
TOWNSHIP 4 SOUTH, RANGE 4 EAST,
MARSHALL COUNTY, OKLAHOMA.
SCALE:
660'
SQUARES COVER 10 ACRES EACH.
INSTRUMENT WORK BY J.F. HOSTERMAN.
GEOLOGY BY C.W. TOMLINSON.
1923.
Turkey Creek
ANTICLINAL AXIS
EAST 1/4-CORNER OF SECTION 34
Qal = Recent Alluvium.
Qt = Alluvial Terrace Deposits.
Kts = Sandstones
Ktl = Basal Limestone
Kt = Trinity Formation.
Ms = Sycamore Limestone.
Dw = Woodford Chert.
Sh = Hunton Limestone.
Ov = Viola Limestone.
Qt includes also talus.
Probable boundaries of Paleozoic formations beneath unconformable cover of younger rocks.
Sulphur seepage
Sulphur spring
Ktl
Kt
Kts
Qt
Qal
Ov
Sh
Dw
Ms

FIG. 2

bedding planes corresponding to those in the solid Woodford chert below. This subsoil layer is marked off from the solid chert by a black marcasitic strip ¼ to 2 inches wide, which varies about 2 feet from the horizontal in the length of this outcrop (about 100 feet). Middle outcrops consist of interbedded black chert and green shale, more or less iron stained on the weathered surface. The northernmost outcrops show 40 feet of black chert and white siliceous clay

FIG. 3.—Viola limestone at north end of the exposure on Turkey Creek, overlain by massive limestone of the Trinity formation. Looking N.N.W. on the southwest flank of the Mannsville anticline, close to its axis.

or clayey chert, banded in layers from a fraction of a millimeter up to 7 inches thick. The lowest 9 feet is all black, the next 9 feet all white chert, and the next 7 feet banded, white, brown, and gray.

Hunton formation.—This formation in the Mannsville area shows the following sequence:

Feet	
18	Very fine grained, white to drab, blocky to platy, noncrystalline limestone
6	Coarsely crystalline, white, medium massive limestone in beds 3 to 24 inches thick, crammed with crinoid rings; grading at base into dense drab glauconitic limestone carrying many fossils, including brachipods and gastropods. A collection from this horizon was identified by Mr. D. K. Greger as belonging to the Henryhouse shale subdivision of the Hunton formation.

Feet
9 Dense white thin-bedded limestone, platy to blocky; more or less chalky
15 Concealed interval
13 Massive, drab, finely crystalline limestone
10 Medium coarsely crystalline drab limestone, massive to irregularly blocky
9 Finely crystalline drab gray limestone, massive to irregularly blocky, with many seams and lenses of drab chert
60 Concealed interval above Viola limestone (Sylvan shale?).

At the sulphur spring shown in the southeast corner of the accompanying detail map, there is exposed 40 feet of massive chalky limestone of the Trinity formation containing abundant fragments of Woodford chert, blocky dense white limestone of the Hunton formation, and possibly some Viola limestone. The fragments range up to 15 inches in length, but most of them are less than 3 inches in diameter. This is overlain by massive white to cream sandstone. The small sulphurous seepage emerges near the base of the chalky limestone, 3 feet above the creek level. There is a small amount of native sulphur coating the rocks and suspended in pool.

At the other sulphur seepage, a thousand feet farther northwest, there is a small outcrop of dense white hackly limestone, like the uppermost part of the main group of Hunton exposures. Its structure is vague, but it appears to have a northwest strike and a southwest dip of about 50 degrees. The slight sulphurous seepage is at the south end of this outcrop.

Viola limestone.—This formation consists of solid bluish gray to drab minutely crystalline limestone, very solid and hard, in part massive and rather poorly bedded, but mostly in well-defined beds 6 inches to 2 feet thick. Occasional layers of cream-colored chert of irregular thickness (up to 3 inches) and extent are present. About 10 feet below the top of the Viola exposures occur 4 or 5 feet of hard dense black bituminous shale, weathering gray. A total of about 250 feet of Viola is exposed. No well-defined fossils were observed in it.

The main Viola outcrop is overlain by a 20-foot cliff of extremely massive, crystalline, cream-colored to buff soft limestone belonging to the Trinity formation, containing drab or bluish-gray pebbles of Viola limestone, layers of quartz pebbles, and much coarsely crystalline calcite in pockets and irregular seams. Along the north edge of the area covered by the accompanying detail map this limestone is broken by a remarkably well developed series of vertical joints trending in a direction 72 to 85 degrees east of north. This

simulates vertical bedding, and was at first mistaken by the writer for a continuation of the Viola outcrop.

STRUCTURE

The outcrops above described, with the exception of the northernmost and easternmost part of the Viola exposures, strike northwest, and dip southwest at angles ranging from 41 to 65 degrees. In general the strike shifts toward the north as the north end of the group of outcrops is approached. In the northernmost Viola outcrops, there is a distinct semicircular swing of the strike around the nose of an anticline which plunges steeply to the northwest, so that in the extreme north end of the Viola exposures the strike is due northeast. In the easternmost extremity of the Viola exposures, in a narrow tributary ravine, there is additional though somewhat less conclusive evidence of an anticlinal axis, as shown on the detail map.

Four or 5 miles northwest of the outcrop above described, there are excellent exposures of a northwestward plunging anticline in the Glenn formation (Pennsylvanian), which extends from the NE¼ of Sec. 19, T. 4 S., R. 4 E., across the south half of Sec. 18, T. 4 S., R. 4 E., and dies out near the west line of the NW¼ of Sec. 13, T. 4. S., R. 3 E. These Pennsylvanian exposures led to a search of the ravines farther southeast and to the discovery of the pre-Pennsylvanian outcrops on Turkey Creek. The latter occur exactly in the trend of the plunging anticline exposed in the Pennsylvanian rocks, and are believed to represent a higher part of the same anticline, which probably extends continuously beneath the intervening cover of Trinity limestone and sand, and continues on to the southeast beyond Turkey Creek. Two dry holes on the Sacra farm in Secs. 17 and 18, T. 5 S., R. 5 E., which attained depths of 2,336 and 3,004 feet, respectively, stopped in black shale which the deeper well had penetrated about 2,500 feet. This is probably the Caney shale, and these records may be utilized to give an approximate outline of the area of the pre-Pennsylvanian rocks beneath the Trinity. It is not impossible that the tiny Madill oil pool in the Trinity sand in Sec. 25, T. 5 S., R. 5 E. was localized as much by the existence of an underlying extension of this Mannsville anticline, as by any local structure in the Trinity itself. This pool is almost directly in line with the trend of the Mannsville anticline, and may possibly be underlain by a southeastward plunging nose in the Glenn formation.

THE CORRELATION OF THE PERMIAN OF KANSAS, OKLAHOMA AND NORTHERN TEXAS

CHARLES N. GOULD
Norman, Oklahoma

ABSTRACT

The Permian rocks of Kansas, Oklahoma, and northern Texas occupy an area about 600 miles long and averaging 125 miles wide. About midway between the northern and southern limits of the exposed Permian are the major structural features known as the Wichita and Arbuckle mountains and the Anadarko basin.

The Permian consists of red beds and non-red sediments. The beds are composed chiefly of red clay shales with interbedded sandstones, gypsums, dolomites, and beds of rock salt; the non-red sediments consist chiefly of limestones and shales. The line of change of color between the red and the non-red sediments transgresses the strike of the rocks at an acute angle, and at about the same distance north and south of the major structural features mentioned above.

Among important results of work done during the past few years are: the recognition of the Anadarko basin and the correlation of the San Angelo–Duncan–Harper sandstone, the Blaine gypsum, and the Whitehorse sandstone from southern Kansas, across Oklahoma to the Colorado River in Texas. Oklahoma equivalents of the Double Mountain formation of Texas have been recognized.

INTRODUCTION

It is the object of this paper to present briefly the larger outlines of the Permian problem in Kansas, Oklahoma, and northern Texas, to state some of the more important recent discoveries, and to correlate certain formations. The Permian in the Pecos and trans-Pecos region of Texas is not considered.

AREAL GEOLOGY

The accompanying map (Fig. 1) shows the surface outcrops of the Permian and related rocks in Kansas, Oklahoma, and northern Texas. In Kansas the Permian occupies a triangular area extending from the Nebraska line south to Oklahoma and west nearly two-thirds the distance across the state. In Oklahoma the Permian extends as a broad belt from Kansas south to Red River, occupying much of the western half of the state. In Texas the Permian extends from Red River south to the Colorado, a distance of about 200 miles. The area of outcrop of the Permian in the three states is about

FIG. 1.—Map of Permian rocks of Kansas, Oklahoma, and northern Texas

600 miles long, averaging perhaps 125 miles in width, the total area being approximately 75,000 square miles.

Approximately midway between northern Kansas and Colorado River, Texas, there occur certain major structural features known as the Wichita and Arbuckle mountains and the Anadarko basin. The Arbuckles and Wichitas are elevated, truncated domes with granite cores flanked with sedimentary rocks of Lower Paleozoic age. The Wichitas constitute an island in the Permian, while the western extremity of the Arbuckles projects into the eastern margin of the Permian. The broad syncline known as the Anadarko basin lies north of the Wichita Mountains, extending from a point near the west end of the Arbuckles an indefinite distance to the northwest. The causes for this structural trough, as well as its limits, are not now definitely understood. It has been suggested that the Anadarko basin represents the northwest extension of the Mill Creek syncline of the Arbuckle Mountains. On the other hand, some believe that it is the reflex to the north, away from the mountains, being a continuation of the dips on the north side of the Arbuckle and Wichita mountains, and possibly also along the north side of the buried Amarillo Mountains of the Texas Panhandle.

On the map (Fig. 1) is shown the line of Pennsylvanian-Permian contact, as the latter is now generally understood. This contact between the Pennsylvanian and Permian is somewhat uncertain as it has been shifted up and down the geologic column in Kansas and Oklahoma throughout a distance of several hundred feet at various times and by various men. There are eminent geologists today who would even place this contact as high as the Herington limestone. The United States Geological Survey would place it at the Cottonwood limestone. In Texas the line between the Cisco beds of the Pennsylvanian and the Permian Wichita beds has not been sharply drawn. The accompanying map attempts to locate the line where Beede placed it, namely, at the outcrop of the Neva limestone in Kansas and Oklahoma.

The map also indicates the approximate location of the change of color, separating the red from the non-red Permian. Practically all writers on the subject have remarked this phenomenon. In traveling over the Permian from northeast to southwest, following

the strike of the beds in southern Kansas and northern Oklahoma, one notes that the rocks, which in east-central Kansas are non-red and composed chiefly of limestones and drab and gray shales, gradually give place to rocks that are red. Not only does the color change, but the lithologic character of the rocks undergoes alteration also; the shales become more sandy, while the limestones gradually thin out. At about the location of the color-change line the shales change from drab and gray to red, and farther south the sandstones also become red. A few prominent limestone beds, such as the Cushing, Neva, Wreford, Fort Riley, Winfield, and Herington, persist, sometimes for many miles, into the area of the red beds, but these limestones all disappear eventually.

Not only do the Permian rocks change their color and become red, however, but this red color transgresses east, beyond the eastern limit of the Permian, into the area occupied by rocks of Upper Pennsylvanian age. In east-central Oklahoma there is a strip of territory averaging 12 to 20 miles wide, extending north from the Arbuckle Mountains for a distance of over 100 miles, as far as Cimarron River in Payne County, where the rocks, which are considered of Pennsylvanian age, are predominatingly red in color and are not easily distinguished lithologically from Permian rocks.

The same general conditions, but in reverse order, are found to occur in Texas. In this state one encounters the same gradual change of color in the rocks. The beds originally called "Albany," by Cummins, consist of non-red Permian, chiefly limestone and drab shale, very similar in character to those in southern Kansas and northern Oklahoma. So similar are these features that the geologist standing on the Leuders limestone scarp west of Albany, Texas, and looking eastward across the country, might well imagine himself standing on the Wreford limestone at the crest of the Flint Hills of eastern Cowley or Butler counties, Kansas. The same succession of westward-dipping limestones and shales, with the same erosional features, are present in both localities.

On coming north these limestones disappear, the shale becomes sandy, and the color of the shale gradually changes. Still farther north the color of the sandstone changes, until, in the region of Archer, Baylor, Wichita, northwestern Clay, and southeastern

Wilbarger counties, the rocks are typical red beds and are known as the Wichita formation. These conditions have been set forth by Gordon.[1] There is a small area in southeastern Clay and northwestern Montague counties which has usually been classed as Pennsylvanian, where the rocks are red in color, corresponding to the area of red Pennsylvanian in east-central Oklahoma.

It appears to be a very significant fact that this line of color change, which cuts diagonally the strike of the Permian formations in northern Texas as well as in southern Kansas and northern Oklahoma, occurs at about the same distance north and south of the Arbuckle-Wichita-Anadarko structural features. The fact has been held by some writers to suggest that the chief source of the Permian sediments should be sought in the Arbuckle and Wichita mountains.

CORRELATION

One of the chief difficulties confronting the student of the Permian problem on the Great Plains has always been the matter of correlation. Invertebrate fossils are common in the non-red Permian of both Kansas and Texas, but are rare in the red beds. Vertebrates occur plentifully in the red beds of the Wichita and Clear Fork of northern Texas, and sparingly in northern Oklahoma and southern Kansas. Plant fossils occur in Kansas, Texas, and northern Oklahoma. The work of various paleontologists, especially of Beede on invertebrates, Williston and Case on vertebrates, and Sellards and David White on plants, has done much to aid in the solution of these matters of correlation. Until recently, however, stratigraphy has been of little help, since no single formation has been known which could be traced uninterruptedly from Kansas, across Oklahoma, into Texas.

Work done by several geologists during the last three years, the results of which were crystallized at the time of a field conference held in southwestern Oklahoma in January, 1924, has thrown considerable light on the subject, and we are now able to trace definitely at least one Permian formation throughout the three states, with a strong probability that other formations above and below it may

[1] C. H. Gordon, "Geology and Underground Waters of the Wichita Region, North-Central Texas," *U.S. Geol. Survey, Water Supply Paper No. 317* (1913), pp. 21–29; map, p. 5.

also be correlated. The formation which can be so traced and which forms the key bed of the Permian is the Blaine gypsum.

Two decades ago the writer followed the Blaine from a point on Medicine Lodge River in northwestern Barber County, Kansas, south to the Kansas-Oklahoma line, and thence south along the outcrop of the "Gyp Hills" of western Oklahoma as far as the northwest corner of Canadian County, beyond which point the gypsum could not be distinguished. In southwestern Oklahoma a formation composed of alternating beds of gypsum and clay was discovered and named the "Greer" formation. For reasons which cannot be fully discussed here it was believed that the "Greer" formation occupied a stratigraphic position higher than that of the Blaine, being separated from the latter by the "Woodward" formation, which included the Dog Creek shales, the Whitehorse sandstone, and the Day Creek dolomite. Subsequent studies by a number of geologists, however, have shown that this classification is in error.

It was determined during the 1924 field conference that although definite beds of gypsum are not always present, the general horizon of the Blaine formation may be followed by means of associated dolomites and by subjacent and superjacent shale and sandstone ledges from Canadian County southeast, outcropping along the north flank of the Anadarko basin, swinging around the head of this basin in southern Grady and northern Stephens counties, and doubling back along the south flank of the basin until the horizon can finally be correlated with the gypsum formerly known as the "Greer" gypsum in southern Washita, northern Kiowa, and southeastern Beckham counties. This formation is especially well exposed at Cedartop Mound, the type locality of the "Greer" at the northwest corner of Kiowa County. From Cedartop it may be traced into Greer, Harmon, and Jackson counties, Oklahoma, and across Red River into northern Texas, and in the latter state as far as Colorado River.

As there is now no justification for retention of the name "Greer," the writer has recommended that this term be abandoned.[2]

[2] Charles N. Gould, "A New Classification of the Permian Redbeds of Southwestern Oklahoma," *Amer. Assoc. Pet. Geol. Bull.*, Vol. 8, No. 3 (May-June, 1924), p. 340.

Beede,[1] in his work in northwestern Texas, has traced a formation long known as the San Angelo conglomerate, and later as the Blowout Mountain sandstone, from its type locality at San Angelo, northward across Red River into Jackson County, Oklahoma. This sandstone, or at least its approximate stratigraphic equivalent, has been followed farther around the northwest extension of the Wichita Mountain arch, doubling back on the south side of the Anadarko basin to correlate with a sandstone, first described by Wegemann,[2] near Duncan, and known as the Duncan sandstone. It has been farther traced around the east end of the Anadarko basin in western Garvin County, at which point it is not more than 12 miles distant from the western extension of the Arbuckle Mountains, and thence north into central Oklahoma as far as Canadian River, near Mustang, Canadian County. Aurin and Clark[3] believe that this sandstone may be traced still farther north, across north-central Oklahoma, and correlated with the Harper sandstone first described by Cragin in Harper County, Kansas.

It may be noted (Fig. 1) that the San Angelo–Duncan sandstone lies just east of, and usually only a few miles distant from, the outcrop of the Blaine, which formation, throughout the greater part of Oklahoma and northern Texas, forms a prominent escarpment long known as "Gyp Hills."

If our correlation is correct, as we now have reason to believe, and the equivalence of the San Angelo–Duncan–Harper may be established, it will be seen that there are two known definite stratigraphic units which may be traced uninterruptedly from Kansas to Texas, namely, the Blaine and the San Angelo–Duncan–Harper.

It is now believed that the Wichita–Clear Fork beds of northern Texas occur in the vicinity of the Wichita Mountains, and between these mountains and Red River, occupying the area originally described by the writer as "red beds of uncertain relations."[4] It has

[1] J. W. Beede, "The Geology of Runnels County, Texas," *The University of Texas Bull. No. 1816* (March, 1918), pp. 6–8. Also "Geology of Coke County, Texas," *ibid., No. 1850* (September, 1918), pp. 19–29.

[2] Carrol H. Wegemann, "The Duncan Gas Field," *U. S. Geol. Survey Bull. 621 D* (1915), p. 44; Charles N. Gould, *op. cit.*, p. 326.

[3] Personal communication.

[4] Charles N. Gould, "Geology and Water Resources of Oklahoma," *U. S. Geol. Survey Water Supply Paper No. 148* (1905), p. 73.

not so far been found possible, however, to differentiate the Wichita from the Clear Fork in Oklahoma. On the colored geologic map of Oklahoma by Miser the separation between the Wichita-Clear Fork beds to the south, and the Enid beds to the north, has been placed at an arbitrary line located in southwestern Garvin County, at the point where the western extension of the Arbuckle Mountains approaches nearest to the easternmost exposure of the Duncan sandstone. On the map (Fig. 1) this line of separation is indicated by a short dotted line.

In Texas the San Angelo sandstone is considered by Beede and others as the base of the Double Mountain formation, and in view of the fact that the San Angelo has now been correlated with the Duncan, which is known to swing around the Wichita Mountain arch and the Anadarko basin and to be correlated tentatively with the Harper sandstone of Kansas, it naturally follows that all Permian formations in Oklahoma and Kansas, above and including the Duncan and Harper, constitute the equivalent of the Double Mountain of Texas.

CONCLUSIONS

In October, 1925, a field conference of some twenty-five geologists, including Dr. E. H. Sellards, associate director of the Bureau of Economic Geology of Texas, and Dr. Beede, was held in western Texas for the purpose of studying the Double Mountain formation and correlating certain members of this formation with known ledges in Kansas and Oklahoma. The results of the observations made at this conference may be summarized as follows:

1. The general stratigraphic units of the Upper Permian red beds are continuous in Kansas, Oklahoma, and Texas.

2. The gypsum-bearing formations are more pronounced in Texas than in the states to the north, both in thickness of the horizons containing large amounts of gypsum and in the number of the individual gypsum beds. The culmination of the gypsum appears to occur near the Double Mountains in southwestern Stonewall County, Texas, from which point the gypsum decreases in amount both to the north and to the south.

3. The Double Mountain formation in Texas corresponds to the following formations in Oklahoma (oldest beds named first):

Duncan-Harper, Chickasha, Blaine, Dog Creek, Whitehorse, Day Creek, Cloud Chief, and Quartermaster.

4. The Duncan of Oklahoma is the approximate equivalent of the San Angelo of Texas. The Blaine gypsum of Oklahoma is the approximate equivalent of the Eskota gypsum of Texas.[1] The Whitehorse sandstone of Oklahoma is the approximate equivalent

TENTATIVE CORRELATION OF THE PERMIAN RED BEDS OF KANSAS, OKLAHOMA, AND NORTHERN TEXAS

Kansas		Oklahoma		Texas	
Cimarron	Big Basin*		Quartermaster	Double Mountain	Red sandy shales
	Hackberry		Cloud Chief ("Greer")		Gypsiferous red shales
	Day Creek	"Woodward"	Day Creek		
	Whitehorse ("Red Bluff")		Whitehorse		Whitehorse ("Lake Trammel")
	Dog Creek		Dog Creek		Gypsiferous red shales
	Blaine ("Cave Creek")		Blaine		Blaine ("Eskota," "Greer")
	Flowerpot	Enid			
	Cedar Hills		Chickasha		Gypsiferous red shales
	Salt Plain				
	Harper		Duncan		San Angelo
	Wellington			Clear Fork	Choza
	Marion				Vale

* The relations of the Big Basin and Hackberry of Kansas to the Quartermaster and Cloud Chief of Oklahoma are not clearly understood at present.

of the Lake Trammel sandstone of Texas.[2] The Day Creek of Oklahoma probably does not persist as far as Texas, but other dolomites do occur in the Double Mountain in Texas. The stratigraphic equivalents of the Chickasha, Dog Creek, Cloud Chief, and Quartermaster have not received distinctive names in Texas, and in view of the fact that the same general horizons are continuous in the two states, it will be well, at least for the present, to use the Oklahoma names. The upper Double Mountain formations, including the Dog

[1] J. W. Beede, "The Geology of Coke County, Texas," *University of Texas Bull. No. 1850* (September, 1918), pp. 29, 53.

[2] W. E. Wrather, "Notes on the Texas Permian," *Bull. Amer. Assoc. of Pet. Geol.*, Vol. 1 (1917), table following p. 96.

Creek, Whitehorse, Day Creek, Cloud Chief, and Quartermaster, are not shown on the map (Fig. 1).

It will also be understood that, using Kansas names, all of the Cimarron series of Cragin, including, from below, the Harper, Salt Plain, Cedar Hills, Flowerpot, Cave Creek, Dog Creek, Red Bluff, Day Creek, Hackberry, and Big Basin, are equivalents of the Double Mountain.

The Wichita and Clear Fork beds of Texas are correlated with the lower part of the Enid, and include the Council Grove, Chase, Marion, and Wellington groups of Kansas and Oklahoma.

The correlation table given herewith attempts to set forth the subdivisions of the red beds of the three states and their relation to other Permian and Pennsylvanian formations. No attempt is made at this time to correlate the non-red Kansas Permian, including the Council Grove, Chase, and Marion formations, with the non-red "Albany" Permian group of Texas, including the Admiral, Belle, Plain, Clyde, and one unnamed formation.

TEXAS JACKSON FORAMINIFERA

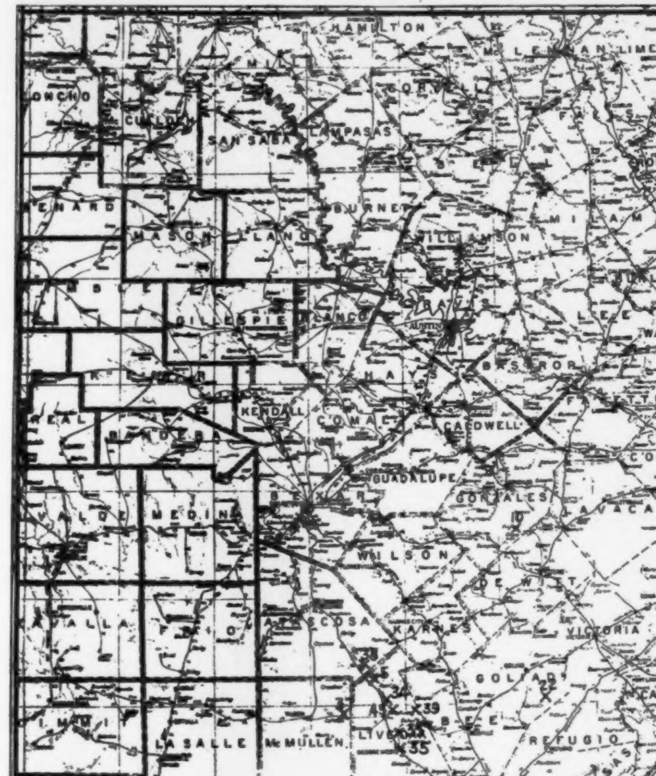
J. A. CUSHMAN AND E. R. APPLIN

INTRODUCTION

Until about three years ago our knowledge of the Texas Jackson was confined to the narrow band of outcropping beds which extends in a semicircle across the state from the Sabine on the east to the Rio Grande in the extreme southwest. These beds are largely composed of clays and sandstones, of which the sandstones are more generally fossiliferous. The fossils are usually preserved as casts, or are so fragile and often crushed as to make their close determination extremely difficult. A very good collection of Jackson fossils from eastern Texas was made by Baker and Suman during their survey of that area, and P. L. Applin and Lyman Reed have recently made a similar collection from southwestern Texas. In studying this material it was found that the clays, and less frequently the sands, often carried a very good fauna of foraminifera which was as clearly defined, constant, and as easily recognized as a fauna of similar numbers of larger fossils would have been.

In a few instances a fauna of foraminifera, which, from its stratigraphic position, we presumed to be Jackson, had been secured from wells in the coastal area. One of the earliest of these was the fauna found in the Texas Exploration Company well, Warren No. 4, Hockley, Harris County, in January, 1922. The well and outcropping faunae were found to correspond, and subsequent work has repeatedly confirmed this discovery. Thus a large new field of Jackson territory was opened for exploration.

Our knowledge of the southern limit of the Jackson beds has now been extended to the vicinity of the present coast line, and the foraminiferal fauna is so well known that it has been subdivided into a number of easily recognized faunules which have a definite stratigraphic relationship and can be traced across the present wide geographic extent of the Jackson formation in this state (Plate 5).


HAMILTON
CONCHO
COLEMAN
SAN SABA
LAMPASAS
CORYELL
MENARD
MASON
LLANO
BURNET
WILLIAMSON
KIMBLE
GILLESPIE
BLANCO
TRAVIS
LEE
HAYS
BASTROP
KENDALL
COMAL
CALDWELL
REAL
BANDERA
GUADALUPE
BEXAR
GONZALES
MEDINA
WILSON
DE WITT
KARNES
VICTORIA
FRIO
ATASCOSA
GOLIAD
LA SALLE
McMULLEN
BEE
REFUGIO
SAN PATRICIO
WEBB
DUVAL
JIM WELLS
NUECES
KLEBERG
ZAPATA
JIM HOGG
BROOKS
KENEDY
STARR
HIDALGO
WILLACY
CAMERON
47
41
39
35


TEXAS
MAP SHOWING LOCALITIES.
GULF OF MEXICO

It is the purpose of this paper to discuss these faunules and their interrelationships, and to describe and figure the common species of foraminifera of which they are composed. This is done so that certain general, well-determined facts regarding this formation may be made available to a larger number of paleontologists now engaged in micro-paleontological work and form a basis for finer detailed studies in the future. The faunules will be discussed in the order of their stratigraphic occurrence, beginning with the highest members and descending in the order in which they would be encountered in wells drilled through the formation. Three major zones, the *Textularia hockleyensis*, *Textularia dibollensis*, and the *Bulimina jacksonensis*, and several minor zones (the *Discorbis jacksonenis*, var. *texana*, *Textularia distortio*, and *Nonionina whittsettensis*) are described.

The foraminiferal fossiliferous portion of the Jackson formation in southern Texas usually consists of black or very dark-brown clay shales, which often form the so-called "heaving shales" of the domal area. In western and in eastern Texas the beds are generally more sandy, and dark gray argillaceous sands often contain a good fauna of foraminifera. More rarely chocolate-colored and pale green unctuous clays form the fossil-bearing horizons.

RELATIONSHIPS OF THE TEXAS UPPER EOCENE TO THAT OF ADJACENT REGIONS

The Upper Eocene of the gulf coastal plain, from Florida to Texas and southward to the eastern coast of Mexico, is one general area of deposition. The easternmost portion of Florida and Georgia is marked by large inshore forms, but very much of the material from Mississippi, Louisiana, Texas, and Mexico is very fine-grained clay, and was probably deposited under offshore conditions. The predominance of the Lagenidae, with an abundance often of *Nodosaria*, *Cristellaria*, and *Uvigerina*, indicate that there was, during parts of this period, a very considerable depth of water. When Berry's map, showing the transgression of the Upper Eocene of the gulf-coastal-plain region of the United States and Mexico, is studied, it will be seen that parts of this area were at a considerable distance from our present coast line, and it is probable that there was fairly deep water

[1] *U. S. Geol. Survey Prof. Paper 95 F* (1915), p. 80.

over the area from which some of the well samples included in this paper were deposited.

For this reason many of the species had a wide distribution, such as do those of the present time, occurring on the continental shelf. An example of this is *Hantkenina alabamensis* Cushman, which is known from numerous stations from the region of its type locality in Alabama, across the states to the west, appearing again in Texas in the well samples, and also known from the Alazan clays of Mexico. This species is characteristic of the Cocoa sand, and seems to be limited to that general horizon. It is related to other species found in the Eocene of Mexico, and also in the Upper Eocene of Southern and Central Europe. It is, therefore, one of the best markers for this particular portion of the formations. Occurring with it, and widely spread, are *Bulimina jacksonensis* Cushman, and many other species.

The *Discorbis* bed, which has been distinguished in the Upper Jackson of Texas, seems to be equivalent to the Yazoo clay of the eastern part of the gulf coastal plain, while the *Bulimina* zone is the equivalent of the Cocoa sand. These members can be distinguished as far south as the coastal plain of Mexico.

Altogether the fauna is a well defined one, very few of the species extending upward into the lowermost Oligocene, while the characteristic ones are known only from the uppermost Eocene of the gulf coastal plain of the United States and Mexico, and are related to, and in some cases identical with, those of the uppermost Eocene of Europe. The fauna of the Texas Jackson, as a rule, seems to be much more meager than that of either the equivalent Alazan of Mexico or the Jackson of the eastern gulf coastal plain of the United States. This is probably due to the much greater amount of material available from the other regions, rather than the lack of species in the Texas region.

ACKNOWLEDGMENTS

We wish to express our gratitude to Dr. E. T. Dumble for his help and guidance in directing the making of collections, organizing and interpreting the information, and granting the opportunity to summarize the results in their present form. It is only through his

constant encouragement and advice, extending over a number of years, that this report has been made possible.

We are also deeply indebted to Mr. W. R. Scott, president of the Rio Bravo Oil Company, for approving the expenditures to undertake this work.

Thanks are also due to Mr. Ray Baker and Miss Hedwig Kniker, of the Texas Company, for their assistance in permitting Mrs. Applin to study and list the fossils from two of their wells.

DISCUSSION OF THE ZONES

Discorbis jacksonensis, VAR. *texana* ZONE

This zone is largely composed of *Discorbis jacksonensis*, var. *texana*, and a few specimens of *Nonionina* cf. *scapha*. It has never been found at the outcrop, either because the conditions of deposition or preservation were not favorable in the area where these beds crop out, or because the foraminifera-bearing stage was not exposed or not found, although careful sections have been made across the known exposures of the Jackson formation. At best, it is a very meager fauna, both in numbers and in species. Also, its position in the section is not constant, for although it occurs characteristically near the top of the Jackson, in well sections studied near the outcrop in eastern Texas, and is repeated several times in a less typical phase in the same section, a very similar fauna has been found near the base of the Jackson in occasional eastern, western, and southern Texas well-sections. These apparently similar faunas have differences which may later show them to be much more distinct than can be made out at the present time. Although typical of the Jackson, this fauna cannot be considered a horizon marker, at the present time, of as great value in this state as some of the others. Rather, it is an indication of certain, apparently shallow water, fine sandy conditions of deposition, and suggests the fluctuating character of the Jackson sea. We consider it, therefore, as a zone of minor importance, and discuss it only because of the fact that it is a characteristic phase of the Jackson formation, and may be of value in some instances as a marker of that formation when other information is not available.

A list of characteristic species is given below:

Discorbis jacksonensis, var. *texana* zone:
Discorbis jacksonensis, var. *texana*
Nonionina scapha, var.
Siphonina advena, var. *eocenica*
Ammobaculites hockleyensis
Haplophragmoides dibollensis

Textularia hockleyensis ZONE

This is one of the most important zones of the Texas Jackson, and is characterized by a species of *Textularia* from which it takes its name. This *Textularia*, in turn, is named for the dome (Hockley) where it was first found, and where it occurs abundantly in samples taken from the Jackson formation in a number of wells drilled by the Texas Exploration Company. The fauna of this zone, at times, is composed almost entirely of this form and its varieties, and *Cristellaria limbosa*, var. *hockleyensis*, which generally accompanies it. A list of other species common to the zone is given below.

This division of the Jackson is more uniform in its faunal characteristics over a wider geographical area within the state than any of the other zones. Stratigraphically, also, it retains a constant position which, from outcrop exposures, has been determined to be Middle Jackson. One of the best outcrop localities was observed on Bridge Creek, 1½ miles above Angelina River, in San Augustine County. The most eastern occurrence of this zone was found in a well drilled near Burkeville, in Newton County, Texas. From this point, through the aid of many well sections, the zone has been traced westward through Tyler County, across the broad band of territory which embraces the domal area and beyond, through Gonzales, Goliad, Live Oak, and Duval counties, into Starr County in the extreme southwest, where an excellent fauna was obtained in the Marland Oil Company, Kelsey No. 2, at about 1,200 feet. West Columbia is the only important exception to the general statement that this zone is known to occur on practically all of the domes in which the Jackson formation is reached by the drill. On this dome unusual conditions of deposition apparently existed in Jackson times, giving rise to faunules which are not closely allied to those studied from other portions of the Jackson area. The average thickness of

the beds referred to this zone is 150 to about 500 feet, although in a few instances almost a thousand feet of beds have been found.

A list of species common to this zone follows:

Textularia hockleyensis zone:
- *Ammobaculites hockleyensis*
- *Textularia hockleyensis*
- *Textularia mississippiensis*
- *Cristellaria limbosa*, var. *hockleyensis*
- *Cristellaria articulata*, var. *texana*
- *Siphonina advena*, var. *eocenica*
- *Nonionina scapha*, var.
- *Nonionina advena*, var. *inexcavata*
- *Polystomella texana*
- *Nodosaria jacksonensis*
- *Quinqueloculina* sp.?

Textularia distortio ZONE

This is a minor zone, which occurs within the *T. hockleyensis* zone. Because of the distinctive character of the dominant species, *Textularia distortio*, it can be recognized readily and used very conveniently as a horizon marker over small areas. *Textularia distortio*, as its name indicates, gives the impression of having been badly crushed and twisted during the period of its growth. Because of this, at first we did not consider the form a good species, but presumed that it was the result of certain unusual local conditions of deposition. Further researches, however, have shown that the species has as wide and almost as persistent a geographical range as *Textularia hockleyensis*, in which zone it occurs. Like the *Discorbis jacksonensis*, var. *texana* zone, however, its position within the major zone is variable, and therefore we have considered it here merely as a minor zone which may be used, like the *Discorbis jacksonensis*, var. *texana*, for close correlation over small areas and broad correlation over the entire Jackson belt in this state. One of the best outcrop localities for this zone was secured on Bridge Creek, 2½ miles south of White Point, San Augustine County, where the species occurs in light chocolate-colored shales. The species is found occasionally with the typical *T. hockleyensis* association, as in the Kelsey No. 2, already referred to, but in its most usual expression it occurs abundantly, unaccompanied by any other genera or species. It is

generally found in chocolate-colored shales and, less commonly, in black clays, which contain a small amount of carbonaceous matter.

Nonionina whitsettensis ZONE

This fauna, although rare, is distinctly individual and easily recognized. It is named for the species of *Nonionina* which dominates the foraminifera of the zone. It was first found in samples secured by P. L. Applin and Lyman Reed while making a reconnaissance report on the Jackson of southwestern Texas, and is named from the town of Whitsett, in Live Oak County, just north of which good outcrop sections carrying this species were found. Until recently we believed that this species was confined to the southwestern Texas area, but a well drilled in Tyler County, near Rockland, encountered a very good fauna characterized by this form, and it is probable that further study will reveal its presence in various parts of the intervening area, although it may merge indefinitely into the *Textularia hockleyensis* zone, in the upper part of which it occurs. The fauna is very commonly found in the Jackson formation in wells drilled in southwestern Texas.

The following species are common to the foregoing zone.

Nonionina whitsettensis zone:
- *Truncatulina pygmaea*
- *Nonionina whitsettensis*
- *Nonionina scapha*, var.
- *Nonionina hantkeni*
- *Discorbis jacksonensis*, var. *texana*

Textularia dibollensis ZONE

This and the following zone hold a greater interest for the enthusiastic paleontologist than any of the others, since it is better represented in outcrop localities and the fauna is abundant both in numbers and in species. In some respects it resembles the fauna of the *Bulimina jacksonensis* zone, as a number of the species are common to both. The most eastern exposure of this zone was found on the Texas side of Sabine River, about $\frac{3}{4}$ mile below Robinson's Ferry, in Sabine County. The zone was named for a species of *Textularia* which is confined to this division, and was first found in a very good outcrop sample secured on Stoval Creek, 4 miles east of Diboll, in Angelina County. Other good outcrop localities occurred just south of White City, in San Augustine County, and on Tar Kiln

Creek, in northeastern Trinity County. These localities place the age of the zone as the upper portion of the basal Jackson. Through the aid of well sections this division has been traced westward across the same general area occupied by the *Textularia hockleyensis* zone. Unlike that zone, however, the general grouping of the species changes to a rather marked degree when the clays, which compose the eastern Texas and part of the southern Texas section, give place to the fine sandy beds which represent this zone in southwestern Texas. In southern Texas this zone in its typical character occurs at Hull, Sour Lake, Humble, Damond Mound, and Brenham. In southwestern Texas the species present are greatly reduced in numbers. Foraminifera are often abundant, but *Nonionina advena*, var. *inexcavata*, which occurs throughout the areal extent of the zone, becomes extremely common, and is so characteristic that the western phase of the zone is often named for it. One outcrop locality of this western phase was found near Cheapside, in Gonzales County. Like the *Textularia hockleyensis* fauna, this *Nonionina* phase of the *Textularia dibollensis* zone is found in nearly all of the wells which penetrate the lower portion of the Jackson in southwestern Texas.

List of species common to the typical *Textularia dibollensis* zone (those marked with an asterisk are also present in its western phase):

Textularia dibollensis zone:
- **Textularia dibollensis*
- *Textularia mississippiensis*
- *Bolivina jacksonensis*
- *Nodosaria laevigata*, var. *ovata*
- *Cristellaria alato-limbata*
- *Uvigerina gardnerae*
- *Uvigerina gardnerae*, var. *texana*
- *Polymorphina austriaca*, var.
- *Polymorphina communis*
- *Truncatulina pygmaea*
- *Truncatulina americana*, var. *antiqua*
- **Siphonina jacksonensis*
- **Pulvinulina jacksonensis*
- **Nonionina umbilicatula*
- **Nonionina hantkeni*
- **Nonionina advena*, var. *inexcavata*
- **Quinqueloculina* sp.?
- *Massilina* sp.?
- *Globigerina inflata*.

Bulimina jacksonensis ZONE

The true position of this zone has been disputed because its occurrence was first noted on domes in southern Texas, where faulting made its position questionable. In several instances, however, it has been found below the *Textularia dibollensis* zone, and occurred at the base of the Jackson in a well recently drilled near Burkeville, in Newton County. Also, the Humble Company secured an outcrop sample on the Texas side of Sabine River, in Sabine County. The exact location of this sample is not known, but it came from south of Robinson's Ferry, and apparently from near Veatch's basal Jackson locality, which is ¾ mile below the Ferry. An outcrop sample of the same zone was found by E. R. Applin and G. Newman in Alabama, north of Jackson, on the road from McVey to Winn. Its position there, on a hilltop, with definite Upper Claiborne beds exposed at the base of the hill, in a stream bed, indicates that it is possibly Upper Jackson in age, and certain well sections in southern Texas seem to indicate that the zone reappears occasionally at that level. The evidence regarding this point, however, is not well established. Therefore we will describe only its occurrence from the base of the formation, where its position has been clearly shown. So far we have not recognized beds which may be referred to this division in the southwestern Texas area, and have found it in only one well in eastern Texas. It is a very common zone, however, in the domal area, where it is well represented at Hull, Sour Lake, Blue Ridge, Damond Mound, and Humble. It is very probable that the Jackson sea entered this area some time before it spread to the west and north, and during this period deposited beds containing a fauna which gave way to the *T. dibollensis* fauna before the sea reached the other areas. Although this zone does not have as wide an areal extent within the state as the other zones, it bears a closer relationship to the Jackson fauna of Mexico and of Alabama than any of the other zones more typical of the Texas area.

List of common species present:

Bulimina jacksonensis zone:
- *Textularia dibollensis*
- *Textularia mississippiensis*
- *Bolivina jacksonensis*

Bulimina jacksonensis
Nodosaria jacksonensis
Cristellaria fragaria, var. *texasensis*
Cristellaria alato-limbata
Uvigerina gardnerae
Uvigerina gardnerae, var. *texana*
Uvigerina cocoaensis
Uvigerina alata
Polymorphina communis
Discorbis jacksonensis
Hantkenina alabamensis
Siphonina advena, var. *eocenica*
Pulvinulina jacksonensis
Nonionina umbilicatula
Polystomella texana

DESCRIPTION OF SPECIES

FAMILY LITUOLIDAE

Haplophragmoides dibollensis CUSHMAN AND APPLIN, N. SP.

(Plate 6, Figures 1*a*, *b*)

Test planospiral, much compressed, completely involute, slightly depressed at the umbilical region on both sides; chambers rather indistinct, eight or nine in the last-formed coil; sutures indistinct, not depressed, periphery rounded, in the later portions subacute; apertural face convex; wall arenaceous but smoothly finished.

Diameter, 0.60 millimeter.

Type specimens from Ohio Red River well No. 2, 1,056 feet, Tyler County, Texas.

This species was recorded as *Cyclammina cancellata* Brady, var. in Dr. Dumble's list (*Bull. Amer. Assoc. Pet. Geol.*, Vol. 8 [1924], p. 443).

Ammobaculites hockleyensis CUSHMAN AND APPLIN, N. SP.

(Plate 6, Figures 2*a*, *b*)

Test nearly twice as long as broad, very much compressed, involute, early portion close-coiled; later, one or two chambers tending to become uncoiled, periphery rounded; chambers rather indistinct; sutures indistinct; wall coarsely arenaceous, of angular black sand grains.

Length, 1 millimeter; breadth, 0.65 millimeter; thickness, 0.10 millimeter.

Type specimens from Ohio Red River Well No. 2, 400 feet, Tyler County, Texas.

This probably is the species recorded in Dr. Dumble's list (*Bull. Amer. Assoc. Pet. Geol.*, Vol. 8 [1924], p. 443) as *Ammobaculites* cf. *A. foliaceus* Brady.

FAMILY TEXTULARIIDAE

Textularia hockleyensis CUSHMAN AND APPLIN, N. SP.

(Plate 6, Figures 3–6)

Textularia hockleyensis Dumble (*nomen nudum*), *Bull. Amer. Assoc. Pet. Geol.*, Vol. 8 (1924), p. 443.

Test comparatively large, tapering, compressed, the central portion thickest, thence with a depressed area between the center and the periphery; periphery thin, but rounded; chambers numerous, distinct; sutures distinct, and toward the central portion often somewhat limbate, strongly curved, especially toward the periphery; wall arenaceous, but smoothly finished, in end view, rhomboid; the aperture much curved, low.

Length, up to 3 millimeters; breadth, up to 1.25 millimeters.

Type specimens from Bridge Creek, 1½ miles above Angelina River, San Augustine County, Texas.

This species in many ways resembles *Textularia tumidulum* Cushman, but the central portion does not have such definite raised areas on each chamber as in that species, and the sutures are much more distinctly limbate. It is probably an ancestral form of *T. tumidulum*, which is found in the Lower Oligocene.

Textularia distortio CUSHMAN AND APPLIN, N. SP.

(Plate 6, Figures 7, 8)

Textularia hockleyensis, var. *distortio* Dumble (*nomen nudum*), *Bull. Amer. Assoc. Pet. Geol.*, Vol. 8 (1924), p. 443.

Test irregular in shape, variously distorted, much compressed, thickest in the central portion, periphery thin but rounded; chambers numerous, low, and broad; sutures very distinctly excavated, especially toward the median portion of each chamber; wall arena-

ceous, somewhat roughened; aperture curved in end view, the aperture making a very strong crescent.

Length, 1 millimeter or slightly more.

Type specimens from Ohio Red River well No. 2, 890 feet, Tyler County, Texas.

This species has a peculiar form, and at first sight might seem to be accidental, but the same form is known from various parts of the gulf coastal plain in the Upper Eocene, including that of Mexico. In this respect it may be compared with *Cyclammina deformis* Guppy, which also has a rather broad geographic distribution in which the peculiar distorted condition persists.

Textularia dibollensis CUSHMAN AND APPLIN, N. SP.
(Plate 6, Figures 12–14)

Textularia dibollensis Dumble (*nomen nudum*), *Bull. Amer. Assoc. Pet. Geol.*, Vol. 8 (1924), p. 443.

Test small, broad, the early portion with the chambers increasing very rapidly in breadth as added, the upper two-thirds of the test with the sides nearly parallel, periphery broadly rounded; chambers rather indistinct, the last four usually making up at least half the test; sutures indistinct, nearly straight, especially in the later portion; wall finely arenaceous, but rather roughly finished; aperture low, broad.

Length, up to 0.60 millimeter; breadth, 0.30 millimeter.

Type specimens from 4 miles east of Diboll, Angelina County, Texas.

This species has a rather broad range in the Upper Eocene of the gulf coastal plain of the United States and Mexico.

Textularia dibollensis CUSHMAN AND APPLIN, N. SP., VAR. *humblei* CUSHMAN AND APPLIN, N. VAR.
(Plate 6, Figure 9)

Textularia dibollensis, var. *humblei* Dumble (*nomen nudum*), *Bull. Amer. Assoc. Pet. Geol.*, Vol. 8 (1924), p. 443.

Variety differing from the typical in the larger size, more elongate form, more tapering, the greatest width being near the apertural end; the sutures much more distinct and depressed, and the periphery somewhat more acute.

Length, 1.60 millimeters; breadth, 1 millimeter.

Type specimens from Haynes No. 1, 3,175–3,270 feet, near Burkeville, Newton County, Texas.

Textularia mississippiensis CUSHMAN

(Plate 6, Figures 10, 11)

Textularia mississippiensis Cushman, *U. S. Geol. Survey Prof. Paper 129* (1922), pp. 90, 125, Plate 14, Fig. 4; *Prof. Paper 133* (1923), p. 17.

Textularia jacksonensis Dumble (*nomen nudum*), *Bull. Amer. Assoc. Pet. Geol.*, Vol. 8 (1924), p. 443.

Test elongate, fairly broad, thickest in the middle, thence thinning toward the periphery, in end view, biconvex, central portion curved; chambers rather low and broad, especially in the early stages, becoming somewhat higher in the adult; sutures covered by a coarsely arenaceous layer, meeting in the center and at the periphery, leaving the central portion of each chamber uncovered; periphery irregular, not definitely or regularly spinose, chamber walls smooth and finely perforate.

Length 0.40–0.75 millimeter.

This species, which is characteristic of the Lower Oligocene, also persists in the Upper Eocene of Texas and other portions of the gulf coastal plain of the United States and Mexico.

Textularia SP.?

(Plate 6, Figure 15)

There is an elongate form present in the Upper Eocene of Texas, but the specimens are not well enough preserved or in sufficient quantity to warrant description. A figure of a partially complete specimen is given. It is from the Upper Eocene, Ohio Red River well No. 2, 1,056 feet, Tyler County, Texas.

Textularia SP.?

(Plate 6, Figure 16)

Occurring with the preceding species is a larger form, somewhat resembling *Textularia dibollensis*, var. *humblei*, but specimens are incomplete and it has not seemed wise to refer it to a definite species.

Bolivina gracilis CUSHMAN AND APPLIN, N. SP.

(Plate 7, Figures 1, 2)

Test small, slender, slightly curved, very little compressed, composed of numerous chambers, distinct, slightly inflated; sutures distinct; oblique, slightly depressed; wall coarsely perforate, the perforations often falling into a linear arrangement lengthwise of the test; aperture comma-shaped, with a slight trace of a lip.

Maximum length, 0.45 millimeter.

Type specimens from 4 miles east of Diboll, Angelina County, Texas.

This species is widely distributed in the Upper Eocene of the gulf coastal plain of the United States and Mexico.

Bolivina jacksonensis CUSHMAN AND APPLIN, N. SP.

(Plate 7, Figures 3, 4)

Test much compressed, thickest along the median line, periphery slightly keeled or with the keel wanting; chambers numerous, distinct, both the median and peripheral portions extending backward; sutures distinct, slightly depressed; wall thin, translucent, smooth, very finely punctate; aperture elongate.

Maximum length, 0.5 millimeter.

Type specimens from Haynes No. 1, 3,175–3,270 feet, near Burkeville, Newton County, Texas.

This species is widely distributed in the Upper Eocene of the gulf coastal plain of the United States and Mexico.

Bolivina jacksonensis CUSHMAN AND APPLIN, N. SP., VAR.
striatella CUSHMAN AND APPLIN, N. VAR.

(Plate 7, Figures 5, 6)

Test tapering, elongate, without a definite carina, much compressed; chambers numerous, distinct; the sutures curved, limbate, especially in the central region, the early half of the test with very numerous, fine, longitudinal costae.

Length, 0.5 millimeter.

Type specimens from 4 miles east of Diboll, Angelina County, Texas.

The species was referred to in Dr. Dumble's list (*Bull. Amer. Assoc. Pet. Geol.*, Vol. 8 [1924] p. 443) as *Bolivina aenariensis* Costa, n. var.

Pleurostomella jacksonensis CUSHMAN AND APPLIN, N. SP.

(Plate 7, Figures 9*a–c*)

Test elongate, tapering, broadest at about the middle of the last-formed chamber, circular in transverse section; chambers comparatively few, alternating, distinct; sutures slightly depressed; wall marked by series of depressions in longitudinal lines; aperture of the usual type in this genus.

Length, 0.50 millimeter.

Type specimen from Haynes No. 1, 3,175–3,270 feet, near Burkeville, Newton County, Texas.

Virgulina dibollensis CUSHMAN AND APPLIN, N. SP.

(Plate 7, Figures 7*a–c*)

Test much elongate, slender, four and one-half times as long as broad, slightly compressed laterally, especially in the later portion; early chambers irregularly spiral, later ones biserial, the last three chambers making up the last half of the test; sutures distinct but not depressed; periphery not lobulate; wall smooth; aperture elongate, elliptical.

Length, 0.50 millimeter; breadth, 0.11 millimeter.

Type specimens from Haynes No. 1, 3,175–3,270 feet, near Burkeville, Newton County, Texas.

Bulimina jacksonensis CUSHMAN

(Plate 7, Figures 8*a*, *b*)

Bulimina jacksonensis Cushman, *Contrib. Cushman Lab. Foram. Res.*, Vol. 1, Part 1 (1925), p. 6, Plate 1, Figs. 6, 7; Part 3, p. 65.

Test elongate, tapering, the initial end acute, broadly rounded at the apertural end and in adults somewhat contracted; chambers numerous, fairly distinct; sutures not depressed; surface ornamented by very prominent longitudinal costae, usually six to eight in number, platelike, much raised above the general surface, continuous from the apical end to the base of the last-formed chamber in adults;

the outer margin in well-preserved specimens serrate; aperture elongate, comma-shaped.

Length, 1 millimeter or more.

This species is very characteristic of the lower portion of the Upper Jackson in the general gulf coastal region of the United States and Mexico. It is somewhat closely allied to *Bulimina sculptilis* Cushman, which is characteristic of the Lower Oligocene of the gulf coastal plain of the United States. *B. jacksonensis* is a larger species with fewer costae and a generally coarser test, which is probably the ancestral form of *B. sculptilis*. Both these species seem to be remotely related to *B. truncana* Gümbel, which is also figured by Hantken from the Upper Eocene of Hungary.

Bulimina SP.?

(Plate 7, Figures 10, 11)

There is a smooth *Bulimina* from this Upper Eocene which is very similar to a form found in the Upper Eocene of the Moctezuma River, Mexico (Cushman, *Bull. Amer. Assoc. Pet. Geol.*, Vol. 9 [1925], p. 301, Plate 7, Fig. 9). Without a greater suite of specimens, it seems inadvisable to give this a definite specific name at this time. It is a smooth, unornamented form found in the Ohio Red River well No. 2, 1,056 feet, Tyler County, Texas.

FAMILY LAGENIDAE

Nodosaria (*Glandulina*) *laevigata* D'ORBIGNY, VAR. *ovata* CUSHMAN AND APPLIN, N. VAR.

(Plate 7, Figures 12, 13)

Test ovate, longer than broad, circular in transverse section, widest toward the apertural end; the chambers overlapping, few in number, indistinct; sutures indistinct, initial end subacute; aperture radiate, slightly projecting; wall smooth, matte.

Average length, 0.60 millimeter; average breadth, 0.40 millimeter.

Type specimens from 4 miles east of Diboll, Angelina County, Texas.

This species was referred to as *Nodosaria laevigata* d'Orbigny, n. var. in Dr. Dumble's paper (*Bull. Amer. Pet. Geol.*, Vol. 8 [1924], p. 443).

Nodosaria jacksonensis CUSHMAN AND APPLIN, N. SP.

(Plate 7, Figures 14–16)

Test elongate, tapering, gently curved, initial end rounded, ornamented with one to several spines, sides lobulate throughout, more strongly so in later growth; chambers subglobular, fairly numerous, usually ten in well-developed specimens, inflated; length and breadth about equal except the last one or two in the adult, which are slightly longer than broad; sutures distinct, somewhat depressed, of clear shell material; surface smooth, glossy to dull, aperture with a cylindrical neck, the aperture itself not well preserved.

Maximum length, 2.50 millimeters; maximum breadth, 0.35 millimeter.

Type specimens from Haynes No. 1, 3,175–3,270 feet, near Burkeville, Newton County, Texas.

This species has a very wide distribution in the Upper Eocene of the gulf coastal plain of the United States and Mexico.

Nodosaria SP.?

(Plate 7, Figure 17)

There is a fragment, shown on Plate 2, of the apertural end of what is evidently a much elongate, slender species of *Nodosaria*, with a peculiar inflated apertural end. Not enough is shown of this to warrant description. It is from Ohio Red River well No. 2, 537 feet, Tyler County, Texas.

This species was referred to as *Nodosaria* n. sp. A, in Dr. Dumble's list (*Bull. Amer. Assoc. Pet. Geol.*, Vol. 8 [1924], p. 443).

Cristellaria articulata REUSS, VAR. *texana* CUSHMAN AND APPLIN, N. VAR.

(Plate 8, Figures 1, 2)

This variety is of large size, in the young with the chambers close-coiled, but in the adult with the central portion becoming visible, due to the shortening of the chambers which fail to cover the preceding whorl entirely; periphery with a distinct, rounded keel, in the adult with as many as ten to twelve chambers.

Diameter, up to 1.60 millimeters.

Type specimens of the variety from Warren well No. 4, 4,250 feet, Texas Exploration Company, Hockley, Harris County, Texas.

This variety is close to the typical form which is known from the Tertiary of Europe, but this Texas variety seems to be distinct.

Listed as *Cristellaria rotulata* Lamarck in Dr. Dumble's paper (*Bull. Amer. Assoc. Pet. Geol.*, Vol. 8 [1924], p. 443).

Cristellaria limbosa (REUSS), VAR. *hockleyensis* CUSHMAN AND APPLIN, N. VAR.

(Plate 8, Figures 3, 4)

Test differing from the typical form of the species in the fewer chambers, and the broader form in apertural view, the keel perhaps not so broad and thin, and the central umbo not so strongly developed.

Diameter, 0.75 millimeter.

Type specimens from Bridge Creek, 1½ miles above Angelina River, San Augustine County, Texas.

This is evidently related, however, to *Cristellaria limbosa*, which is known from the Upper Eocene of Central Europe.

Cristellaria fragaria GÜMBEL, VAR. *texasensis* CUSHMAN AND APPLIN, N. VAR.

(Plate 8, Figures 5–7)

Test differing from the typical form in the more elongate character of the test, the more coarsely beaded ornamentation, and more deeply excavated sutures, the periphery often decidedly lobulate.

Length, up to 1.25 millimeters; breadth, 0.50 millimeter; thickness, 0.25 millimeter.

Type specimens from Haynes No. 1, 3,175–3,270 feet, near Burkeville, Newton County, Texas.

This species was given as *Cristellaria aculeata* d'Orbigny in Dr. Dumble's list (*Bull. Amer. Assoc. Pet. Geol.*, Vol. 8 [1924], p. 443).

Cristellaria alato-limbata (GÜMBEL)

(Plate 8, Figure 8)

Robulina alato-limbata Gümbel, *Abhandl. kön. bay. Akad. Wiss. München*, Cl. II, Vol. 10 (1868 [1870]), p. 641, Plate 2, Figs. 70*a*, *b*.

Test close-coiled, last-formed coil composed of few chambers,

usually seven in number, the central region with a large umbo not greatly projecting above the general surface, but distinct; periphery with a narrow keel; chambers distinct, not inflated; sutures distinct, not depressed, strongly curved; aperture radiate; wall smooth.

Diameter, 0.65 millimeter.

Specimens from Ohio Red River well No. 2, 400 feet, Tyler County, Texas.

Gümbel described this species from the Upper Eocene from Central Europe, and our Texas specimens seem to fit very closely this description and figure.

Cristellaria propinqua HANTKEN

(Plate 8, Figure 9)

Cristellaria propinqua Hantken, *A magy. kir. földt. int. evkönyve*, Vol. 4 (1875 [1876]), p. 45, Plate 5, Fig. 4; *Mitth. a. d. Jahrb. k. ungar. geol. Anstalt*, Vol. 4 (1876 [1881]), p. 52, Plate 5, Fig. 4.

Test with the early portion close-coiled, later tending to become uncoiled, the periphery subacute, later chambers increasing in width; chambers few, six or seven in the last-formed coil, distinct but not inflated; sutures distinct, curved, not depressed; apertural face somewhat tapering toward the aperture, which is radiate and slightly projecting; wall smooth.

Diameter, 0.60 millimeter.

Type specimens from Ohio Red River well No. 2, 1,056 feet, Tyler County, Texas.

Our Texas specimens are very similar indeed to those figured and described by Hantken in the above reference from the Upper Eocene of Hungary.

This form mentioned as *Cristellaria italica* deFrance, var. in Dr. Dumble's list (*Bull. Amer. Assoc. Pet. Geol.*, Vol. 8 [1924], p. 443).

Cristellaria jacksonensis CUSHMAN AND APPLIN, N. SP.

(Plate 8, Figure 10)

Test much elongate, the greatest width being at the base, where there are a few close-coiled chambers, later portion consisting of three to five uniserial chambers, much inflated, especially toward the apertural end, early portion with the periphery acute, consisting of four or five chambers in the coil, the later uncoiled chamber pro-

gressively increasing in thickness so that the last-formed chamber is often circular in transverse section; sutures distinct, those of the later portion depressed; wall smooth; aperture radiate, terminal.

Length, up to nearly 1 millimeter; breadth at the base, 0.20 millimeter.

Type specimens from Ohio Red River well No. 2, 1,056 feet, Tyler County, Texas.

This species has a wide distribution in the Upper Eocene of the gulf coastal plain of the United States and Mexico.

Polymorphina texana CUSHMAN AND APPLIN, N. SP.

(Plate 9, Figures 1, 2)

Test about twice as long as broad, somewhat compressed, periphery broadly rounded; chambers comparatively few, the last two making up the greater portion of the test, early chambers irregularly spiral, later ones becoming more flattened and somewhat biserial; sutures distinct, slightly depressed; wall smooth; aperture radiate, terminal.

Length, up to 0.80 millimeter; breadth, up to 0.35 millimeter.

Type specimens from Tar Kiln Creek, ½ mile above Neches River, Trinity County, Texas.

Polymorphina communis D'ORBIGNY, VAR.

(Plate 9, Figures 3*a*, *b*)

There are in this Upper Eocene material rounded *Polymorphinas* with a somewhat tapering apertural end, which may be referred with some hesitancy to d'Orbigny's *Polymorphina communis.* Some of the best of these are from Ohio Red River well No. 2, 1,056 feet, Tyler County, Texas.

This form listed as *Polymorphina communis* d'Orbigny in Dr. Dumble's paper (*Bull. Amer. Assoc. Pet. Geol.*, Vol. 8 [1924], p. 443.)

Polymorphina compressa D'ORBIGNY, VAR. *dumblei*
CUSHMAN AND APPLIN, N. VAR.

(Plate 9, Figures 4, 5)

This form differs from the typical in the greater size of the last-formed chambers, the last two usually making up more than half of the size of the test, early chambers somewhat irregularly spiral,

later ones compressed and irregularly biserial; chambers distinct; sutures depressed and distinct; wall smooth; aperture terminal, radiate.

Length, 0.85 millimeter; breadth, 0.40 millimeter.

Type specimens from Bridge Creek, 1½ miles above Angelina River, San Augustine County, Texas.

This form was listed as *Polymorphina* cf. *compressa* Cushman in Dr. Dumble's report (*Bull. Amer. Assoc. Pet. Geol.*, Vol. 8 [1924], p. 443).

Polymorphina austriaca (D'ORBIGNY), VAR. *io* CUSHMAN AND APPLIN, N. VAR.

(Plate 9, Figures 6, 7)

There are in this Upper Eocene material of Texas specimens which in many respects are closely allied to d'Orbigny's figure of *Guttulina austriaca* from the Vienna Basin. Our specimens are more distinctly angled, and have a generally different appearance. They are, however, so near that it has seemed best to make this only a variety of d'Orbigny's species.

Length, 0.60 millimeter; breadth, 0.35 millimeter.

Type specimens from Haynes No. 1, 3,175–3,270 feet, near Burkeville, Newton County, Texas.

Uvigerina cocoaensis CUSHMAN

(Plate 8, Figure 15)

Uvigerina cocoaensis Cushman, *Contrib. Cushman Lab. Foram. Res.*, Vol. 1, Part 3 (1925), p. 68, Plate 10, Fig. 2.

Test of medium size for the genus, elongate, fusiform, greatest width slightly above the middle, periphery very slightly lobulate; chambers rather few, inflated, evenly rounded; sutures slightly depressed; wall ornamented with coarse longitudinal costae, not usually confluent with those of the chambers above or below, becoming lower and less conspicuous in later chambers, the last-formed chamber in the adult smooth, about twelve to sixteen costae in the complete circumference in the widest region; wall finely punctate; apertural end with a short cylindrical neck and phialine lip.

Maximum length, 0.80 millimeter; width, 0.30–0.35 millimeter.

This species described from the Cocoa Sand of Alabama appears

to be present in this Upper Eocene of Texas, occurring at 1,056 feet in Ohio Red River well No. 2, Tyler County, Texas.

Uvigerina gardnerae CUSHMAN, MS.

(Plate 8, Figures 16, 17)

Test of medium size for the genus, much elongate, slender, early portion fusiform, later portion with the chambers somewhat loosely arranged, periphery somewhat lobulate; chambers numerous, inflated, especially the later ones, earlier ones with the basal end of the chambers tending to overhang the preceding ones; wall ornamented with longitudinal costae in the earlier portion, the costae not confluent with those chambers above or below, costae later tending to break up into lines of spines, and the later portion of the test in adults generally hispid, about twenty costae in the complete circumference before the breaking into spines; apertural end with a slightly tapering subcylindrical neck and slight phialine lip.

Maximum length, 0.80 millimeter; width, 0.25 millimeter.

This species described in manuscript from U. S. G. S. Station 6457, 1½ miles south of Shubuta, Wayne County, Mississippi, and named in honor of Dr. Julia M. Gardner, of the United States National Museum, has been found to be present also in this Upper Eocene of Texas, occurring at 1,056 feet in Ohio Red River well No. 2, Tyler County, Texas. It also occurs in the Eocene of the coastal plain of Mexico. It is represented in the Texas material also by the following variety.

Uvigerina gardnerae CUSHMAN, MS., VAR. *Texana* CUSHMAN AND APPLIN, N. VAR.

(Plate 8, Figure 18)

This variety is very similar to the typical form, but is much more elongate, the later portion being somewhat less in diameter than the earlier part.

Length, 0.60 millimeter; breadth, 0.20 millimeter.

Type specimens from Ohio Red River well No. 2, 1,056 feet, Tyler County, Texas.

This form was called *Uvigerina jacksoni* in Dr. Dumble's paper (*Bull. Amer. Pet. Geol.*, Vol. 8 [1924], p. 443).

Uvigerina topilensis CUSHMAN

(Plate 8, Figure 14)

Uvigerina topilensis Cushman, *Contrib. Cushman Lab. Foram. Res.*, Vol. 1, Part 1 (1925), p. 5, Plate 1, Figs. 5*a*, *b*.

Test generally fusiform, broadest in the middle, initial and apertural ends both rounded; chambers irregularly spiral, inflated; sutures distinct, depressed; wall ornamented with a very few costae, progressively decreasing in height toward the apertural end of the test and usually continuous from one chamber to another, the last-formed chamber usually smooth; wall finely punctate, the costae on the earliest portion sometimes projecting backward into platelike processes; aperture with a very narrow cylindrical neck.

Length, 0.70 millimeter; breadth, 0.30 millimeter.

This species described from the Upper Eocene, Alazan clays of Mexico, occurs in the Upper Eocene of Texas at 1,056 feet, in Ohio Red River well No. 2, Tyler County, Texas.

This form given as *Uvigerina* n. sp. in Dr. Dumble's list (*Bull. Amer. Assoc. Pet. Geol.*, Vol. 8 [1924], p. 443).

Uvigerina alata CUSHMAN AND APPLIN, N. SP.

(Plate 8, Figures 11–13)

Test elongate, about twice as long as broad; chambers distinct and inflated; sutures distinct, depressed; wall ornamented with a few very prominent, thin, high, platelike costae, usually extending posterially beyond the limits of the chambers; apertural end of the last-formed chamber truncate, with a very short, cylindrical neck somewhat set down into a depression in the chamber wall.

Length, up to 0.75 millimeter; breadth, 0.30 to 0.35 millimeter.

Type specimens from Ohio Red River well No. 2, 1,056 feet, Tyler County, Texas. This is a very distinct species, not so far recognized from the eastern coastal-plain region of the United States. It has very high, platelike costae with a posterior angle, making it very different from most of the other described species of *Uvigerina*. It resembles more some of the European forms such as *U. cristata* Mariani, etc.

Uvigerina dumblei CUSHMAN AND APPLIN, N. SP.

(Plate 8, Figure 19)

Test large, periphery rounded, the sides nearly parallel for most of its length, nearly twice as long as broad; chambers distinct; sutures slightly depressed; wall ornamented by very numerous, fine, longitudinal costae, often ten to twelve to a single chamber, and extending backward, making the sutures crenulate; the apertural end with a slightly projecting cylindrical neck.

Length, up to 1 millimeter.

Type specimens from Haynes No. 1, 3,175–3,270 feet, near Burkeville, Newton County, Texas.

This is the largest and finest of the *Uvigerinas* of the Texas Eocene, and is named in honor of Dr. E. T. Dumble, who has done so much to foster the paleontology of Texas and Mexico.

FAMILY GLOBIGERINIDAE

Hantkenina alabamensis CUSHMAN

(Plate 10, Figure 3)

Hantkenina alabamensis Cushman, *Proc. U. S. National Museum*, Vol. 66 (1924), p. 3, Plate 1, Figs. 1–6; Plate 2, Fig. 5. Cushman, *Contrib. Cushman Lab. Foram. Res.*, Vol. 1, Part 1 (1925), p. 7, Plate 1, Fig. 11; Part 3 (1925), p. 68.

Test planospiral, compressed, adult coil with five or six chambers, periphery very slightly if at all lobulate, wall very finely punctate, smooth, granular near the aperture, each chamber with a hollow, slender, acicular spine at the periphery, pointing somewhat anteriorly; aperture tripartite, with an elongate projection along each side at the base of the apertural face, and the third, median, extending peripherally from the base of the apertural face.

Diameter, without spines, 0.45 millimeter; with spines, 0.75 millimeter.

This species, which is described from the Upper Eocene of the coastal plain of Alabama, and also recorded from the Upper Eocene, Alazan clay of Mexico, is fairly common in the *Bulimina* zone of the Upper Eocene of Texas. This is one of the species which is widely distributed on the gulf coastal plain of the United States and Mexico,

and makes an excellent marker for this particular part of the Jackson formation.

FAMILY ROTALIIDAE

Discorbis jacksonensis CUSHMAN AND APPLIN, N. SP.

(Plate 9, Figures 8, 9)

Test small, planoconvex, the ventral side flattened, dorsal side only slightly convex, with a distinct, clear umbonal mass, occupying the central region, periphery subacute; chambers numerous, ten or more in the last-formed coil, elongate, distinct; sutures distinct, very slightly depressed and somewhat limbate, on the dorsal side nearly straight until toward the outer half, where they become strongly recurved, on the ventral side sutures much depressed, especially toward the umbilicus, which becomes somewhat open in well-developed specimens; wall smooth, finely punctate.

Length, 0.50 millimeter; breadth, 0.40 millimeter.

Type specimens from Bridge Creek, 1½ miles above Angelina River, San Augustine County, Texas.

Discorbis jacksonensis CUSHMAN AND APPLIN, N. SP., VAR. *dibollensis* CUSHMAN AND APPLIN, N. VAR.

(Plate 9, Figure 10)

This variety differs from the typical in its slightly more rounded form and fewer chambers; chambers being shorter and wider; the sutures more evenly curved and on the dorsal side slightly less developed, umbonate thickening over the central region; wall finely punctate, smooth.

Length, up to 0.50 millimeter; breadth, 0.35 millimeter.

Type specimens from 4 miles east of Diboll, Angelina County, Texas.

Discorbis jacksonensis CUSHMAN AND APPLIN, N. SP., VAR. *texana* CUSHMAN AND APPLIN, N. VAR.

(Plate 9, Figure 11)

Test differing from the typical in the slightly larger size, the more open coil, with consequently shorter, broader chambers.

Length, 0.60 millimeter; breadth, 0.40 millimeter.

Type specimens from Ohio Red River well No. 2, 400 feet, Tyler County, Texas.

Truncatulina americana CUSHMAN, VAR. *antiqua* CUSHMAN AND APPLIN, N. VAR.

(Plate 9, Figures 12, 13)

Test differing from the typical in the more limbate, much more curved sutures, as well as fewer chambers.

Length, 0.40 millimeter; breadth, 0.28 millimeter.

Type specimens from 4 miles east of Diboll, Angelina County, Texas.

Listed as *Truncatulina americana* in Dr. Dumble's report (*Bull. Amer. Assoc. Pet. Geol.*, Vol. 8 [1924], p. 443).

Truncatulina pygmaea HANTKEN

(Plate 9, Figure 14)

There are specimens in this Upper Eocene of Texas which seem to be identical with this species described by Hantken from the Upper Eocene of Central Europe.

Diameter, 0.30 millimeter.

Type specimens from north of Whitsett, Live Oak County, Texas.

This very small species agrees much more closely with Hantken's original material from the Eocene than it does with much of the recent and later Tertiary material referred by many authors to this species.

Anomalina granosa (HANTKEN), VAR. *dibollensis* CUSHMAN AND APPLIN, N. VAR.

(Plate 9, Figure 15)

Test very similar to the typical form of the species, but with a slightly greater number of chambers, which are somewhat less inflated.

Length, 0.40 millimeter; breadth, 0.35 millimeter.

Type specimens from 4 miles east of Diboll, Angelina County, Texas.

Except for the differences noted above, this form from the Upper Eocene of Texas is very close indeed to the species described by Hantken from the Upper Eocene of Central Europe.

Siphonina advena CUSHMAN, VAR. *eocenica* CUSHMAN AND APPLIN, N. VAR.

(Plate 9, Figures 16–19)

Test differing from the typical form of the species, which was described from the Lower Oligocene, in the less prominent spiral suture on the dorsal side, and the more entire periphery; the chambers not showing as definitely as in the typical.

Diameter, 0.40 millimeter.

Type specimens from Tar Kiln Creek, ½ mile above Neches River, Trinity County, Texas.

Siphonina jacksonensis CUSHMAN AND APPLIN, N. SP.

(Plate 9, Figures 20–23)

Siphonina jacksoni Dumble (*nomen nudum*), *Bull. Amer. Assoc. Pet. Geol.*, Vol. 8 (1924), p. 443.

Test much compressed, the chambers slightly projecting at the posterior angle; at the periphery, keeled, five chambers in the last-formed coil, fairly distinct; sutures very slightly limbate on the dorsal side, spiral suture not prominent; wall ornamented by very numerous, small spinose processes, in some specimens distinctly developed so that the periphery of the test is itself spinose; central portion strongly reticulate; aperture elongate, with a slightly projecting neck and lip.

Diameter, 0.50 millimeter.

Type specimens from 4 miles east of Diboll, Angelina County, Texas.

This species may be distinguished by its very much compressed form, and its peculiar spinose and reticulate ornamentation of the surface.

Anomalina affinis (HANTKEN)

(Plate 9, Figures 1, 2)

The specimens from the Upper Eocene of Texas are very similar indeed to a species described by Hantken from the Upper Eocene of Central Europe. The specimens are so identical that there are no differences worthy of varietal distinction.

Specimens from 4 miles east of Diboll, Angelina County, Texas.

Pulvinulina jacksonensis CUSHMAN AND APPLIN, N. SP.

(Plate 9, Figures 24, 25)

Pulvinulina jacksoni Dumble (*nomen nudum*), *Bull. Amer. Assoc. Pet. Geol.*, Vol. 8 (1924), p. 443.

Test with a fairly high spire, the periphery not keeled but only slightly rounded, the dorsal side much more convex than the ventral; chambers numerous, six or seven in the last-formed coil; sutures distinct but on the dorsal side very oblique, on the ventral side only slightly curved and somewhat depressed; wall smooth, the aperture on the ventral side forming a distinct angle in the border of the test and extending to the umbilicus.

Diameter, 0.75 millimeter.

Type specimens from 4 miles east of Diboll, Angelina County, Texas.

This species is close to *Pulvinulina mexicana* Cushman from the Upper Eocene of Mexico, but has fewer chambers. It belongs also in the group with *P. byramensis* Cushman, which it more nearly resembles. *P. jacksonensis* has more coils, often four or five, and fewer chambers than the Lower Oligocene species. It is usually somewhat smaller.

FAMILY NUMULITIDAE

Nonionina advena CUSHMAN

(Plate 10, Figures 16, 17)

Nonionina advena Cushman, *U. S. Geol. Survey Prof. Paper 129* (1922), p. 139, Plate 32, Fig. 8; *Prof. Paper 133* (1923), p. 50.

Test small, circular, in side view, biconvex; periphery rounded, nine to eleven chambers in the last-formed coil, inflated; sutures curved, slightly sigmoid, the inner portion excavated and broadened; umbilical region at each side of the test occupied by a large projecting knob of clear shell material; aperture at the base of the last-formed chamber.

Maximum length, 0.75 millimeter.

This species was described from the Mint Spring calcareous marl member of the Lower Oligocene of Mississippi. What seemed to be specimens of this species occurred in the Upper Eocene of Texas, at an outcrop near Cheapside, Gonzales County, Texas.

Nonionina advena Cushman, var. *inexcavata* Cushman and Applin, n. var.

(Plate 10, Figures 18, 19)

What seems to be a variety of this species occurs in the Upper Eocene of Texas, and may be distinguished by the less umbonate character of the central region, and by the much less, if at all, excavated character of the sutures.

Type specimens from 4 miles east of Diboll, Angelina County, Texas.

Nonionina umbilicatula (Montagu)

(Plate 10, Figures 14, 15)

Referred to this species are numerous specimens of *Nonionina* with a definitely umbilicate character, which are found in the Upper Eocene of Texas. They may later be varietally distinguished from this species, or even prove to be different, but for the present may be left under this name.

Specimens from 4 miles east of Diboll, Angelina County, Texas.

There is a form developed at Bridge Creek, 1½ miles above Angelina River, San Augustine County, Texas, occurring with *Textularia hockleyensis*, which differs from that found lower in the section. It has a decidedly umbonate boss filling the umbilical region, and should probably be distinguished as var. *hockleyensis* Cushman and Applin, n. var.

Nonionina scapha (Fichtel and Moll), var.

(Plate 10, Figures 12, 13)

There are specimens which are here figured belonging to the general group of *Nonionina scapha*. They are from the Whitsett zone, Ohio Red River well No. 2, 537 feet, Tyler County, Texas.

Nonionina hantkeni Cushman and Applin, n. sp.

(Plate 10, Figures 10, 11)

Pullenia elongata Hantken, *A magy. kir. földt. int. evkönyve*, Vol. 4 (1875 [1876]), p. 50, Plate 10, Fig. 10; *Mitth. a. d. Jahrb. k. ungar. geol. Anstalt*, Vol. 4 (1875 [1881]), p. 59, Plate 10, Fig. 10.

Test somewhat longer than broad, consisting of numerous cham-

bers, as many as twelve in the last-formed coil, periphery broadly rounded, the umbilical region slightly exposed, showing the inner ends of the earlier chambers; sutures distinct, very slightly and evenly curved; wall smooth; aperture arched in the base of the apertural face of the last-formed chamber.

This form named as *Nonionina scapha*, var. *hooki* in Dr. Dumble's report (*Bull. Amer. Assoc. Pet. Geol.*, Vol. 8 [1924], p. 444).

Length, up to 0.60 millimeter.

Type specimen from Ohio Red River well No. 2, 2,330 feet, Tyler County, Texas.

There are a number of specimens which seem to be identical with that figured and described by Hantken from the Upper Eocene of Central Europe as *Pullenia elongata* Hantken. From a study of Hantken's figure, however, these seem definitely to belong to *Nonionina*. As d'Orbigny has already used the name *Nonionina elongata*, this species is named after Hantken.

Nonionina whitsettensis CUSHMAN AND APPLIN, N. SP.

(Plate 10, Figures 4–6)

Test much compressed, sides nearly parallel, the periphery broadly rounded; chambers long, narrow, distinct, usually nine in the last-formed coil; the sutures very strongly curved, especially at the proximal end, slightly depressed; retral processes only slightly developed; wall smooth; aperture a very narrow, elongate slit at the base of the apertural face.

Diameter, up to 0.50 millimeter; thickness, 0.10–0.12 millimeter.

Type specimens from Ohio Red River well No. 2, 330 feet, Tyler County, Texas.

This species is very common in the so-called Whitsett zone, and holds its characters very consistently. The three figures below show the extent of its variation; its very narrow form in apertural view, with its parallel sides and broadly rounded periphery, will serve to distinguish it. In some ways it resembles a species described, from Samoa, as *Nonionina subturgida*. It is also somewhat related to *N. turgida* (Williamson).

Polystomella texana CUSHMAN AND APPLIN, N. SP.

(Plate 10, Figures 7–9)

Test nearly circular in outline, the periphery broadly rounded; chambers numerous, eleven usually in the last-formed coil, slightly umbonate; the sutures distinct, slightly depressed, strongly curved; retral processes only slightly developed; wall smooth; aperture a low, arched slit at the base of the ventral face of the last-formed chamber.

Diameter, 0.45 millimeter.

Type specimens from Ohio Red River well No. 2, 537 feet, Tyler County, Texas.

The retral processes are very slightly developed, and in many of the younger specimens it is very difficult to distinguish this species from a *Nonionina*.

This seems to be a common species in certain parts of the Upper Eocene of Texas.

FAMILY MILIOLIDAE

Quinqueloculina SP.?

(Plate 10, Figures 20, 21)

There are a very few specimens, not particularly well preserved, from Stovall Creek, east of Diboll, Angelina County, Texas. These are figured, but it does not seem best to give them a name until more and better material is available.

Quinqueloculina SP.?

(Plate 10, Figures 22, 23)

This species seems to be different from the preceding, especially in its apertural characters, the aperture being much smaller, the test itself comparatively broader; but without more material it is difficult to give it a specific name.

Specimens from Stovall Creek, east of Diboll, Angelina County, Texas.

Quinqueloculina SP.?

(Plate 10, Figure 24)

There is a specimen which is here figured, one side of which seems to be excavated, but whether this is due to the condition of

preservation or is a definite character can only be determined by more material.

It is from Stovall Creek, east of Diboll, Angelina County, Texas.

Massilina sp.?

(Plate 10, Figures 25–27)

There is a fairly large species from Ohio Red River well No. 2, 400 feet, Tyler County, Texas, which is here figured. It is keeled in the adult, and has a projecting apertural end with a short, cylindrical neck. The early portion is evidently Quinqueloculine, but later chambers are in a single plane of coiling, making the species belong to the genus *Massilina*.

LIST OF LOCALITIES

1. Bridge Creek, 1½ miles above the Angelina River, San Augustine County, Texas.
2. Warren No. 4, Texas Exploration Company well, Hockley, Harris County, Texas.
3. Ohio Red River Oil Company, No. 2, 400 feet, Tyler County.
4. Ohio Red River Oil Company, No. 2, 300 feet, Tyler County.
5. Applin and Reed Loc. 125, north of Whitsett, Live Oak County, Texas.
6. Ohio Red River Oil Company, No. 2, 537 feet, Tyler County.
7. Ohio Red River Oil Company, No. 2, 890 feet, Tyler County.
8. Stovall Creek, 3½ miles east of Diboll, Angelina County, Texas.
9. Tar Kiln Creek, ½ mile above Neches River, Trinity County, Texas.
10. Outcrop near Cheapside, Gonzales County, Texas.
11. Tar Kiln Creek, at Mr. Nash's Store, Trinity County, Texas.
12. Stovall Creek, 4 miles east of Diboll, Angelina County, Texas.
13. Ohio Red River Oil Company, No. 2, 1,056 feet, Tyler County, Texas.
14. Haynes No. 1, 3,175–3,270 feet, near Burkeville, Newton County, Texas.
15. About ¾ mile below Robinson's Ferry on Texas side of Sabine River, Sabine County, Texas.
16. Branch of Shawnee Creek, southeast of Manning, Angelina County.
17. Warren No. 5, Texas Exploration Company well, Hockley, 4,067–4,123 feet, Harris County.
18. Hanna No. 1, Hull, Liberty County, Texas, and Vacuum Oil Company, 3,017–74 feet.
19. Hanna No. 1, Hull, Liberty County, Texas, and Vacuum Oil Company, 3,164 feet.
20. Fitzsimmons No. 1—Brenham Dome, Washington County, Texas, 1,063–66 feet.
21. Empire Oil Company No. 1, 1,101–27 feet, Angelina County, Texas.
22. Danforth No. 2, Goliad Northern Oil Company well, Goliad County, Texas, 4,142 feet.
23. Danforth No. 2, Goliad Northern Oil Company well, Goliad County, Texas, 4,632–53 feet.
24. Danforth No. 2, Goliad Northern Oil Company, Goliad County, Texas, 4,678–4,851 feet.
25. Hamil-Smith well, Markham Field, Matagorda County, 3,000 feet.

REVISED LIST OF COMMON SPECIES FROM TEXAS, JACKSON

Table of Distribution

Foraminifera	Localities																																																						
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55
Ammobaculites hockleyensis			X													X				X														X	X					X					X	X								X	X
Haplophragmoides dibollensis			X																	X			X				X	X											X										X						
Textularia hockleyensis	X	X	X			X								X			X	X		X							X				X					X				X					X				X				X	X	
Textularia distortio							X									X				X		X										X							X					X								X			
Textularia dibollensis								X			X	X	X		X								X																						X									
Textularia dibollensis, var. *humblei*														X	X						X			X		X		X																			X							
Textularia mississippiensis	X	X				X		X	X		X	X	X	X	X		X		X	X			X	X	X		X	X																			X	X		X				
Bolivina jacksonensis								X				X	X	X				X	X	X	X														X														X			X		
Bolivina jacksonensis, var. *striatella*												X			X								X	X	X																						X						
Bolivina gracilis								X			X	X	X	X						X				X				X																										
Bulimina jacksonensis														X										X	X																						X	X	X	X				
Bulimina sp.													X	X					X																													X					
Nodosaria (Glandulina) laevigata, var. *ovata*								X	X		X	X	X		X					X				X																								X	X					
Nodosaria jacksonensis														X	X				X					X		X		X		X																	X	X	X					
Cristellaria limbosa, var. *hockleyensis*	X		X														X		X		X		X	X						X	X	X											X		X			X		X	X		X		
Cristellaria alata, var. *limbata*			X								X				X			X	X							X																							X		X				X
Cristellaria articulata, var. *texana*		X													X		X								X																							X	X		X				
Cristellaria propinqua													X		X				X				X	X		X																						X	X		X				
Cristellaria fragaria, var. *texasensis*		X												X	X			X	X					X																							X	X	X	X				
Cristellaria jacksonensis													X						X									X																			X	X						
Uvigerina alata													X		X				X				X	X					X	X																				X				X
Uvigerina dumblei														X																																				X				
Uvigerina cocoaensis													X												X																						X	X						
Uvigerina gardnerae	X												X		X		X	X			X			X		X																					X	X	X				X	
Uvigerina gardnerae, var. *texana*													X		X		X																														X		X	X				X
Uvigerina topilensis												X	X						X					X																														
Polymorphina texana	X								X																																													
Polymorphina compressa, var. *dumblei*	X										X																																											
Polymorphina austriaca, var. *io*								X						X	X																																						X		
Polymorphina communis								X	X		X		X		X		X																																						
Discorbis jacksonensis	X																			X																				X								X	X	X				X
Discorbis jacksonensis, var. *texana*			X	X							X				X		X			X	X				X			X							X	X					X				X	X	X									
Discorbis jacksonensis, var. *dibollensis*									X	X		X			X							X										X								X																
Pleurostomella jacksonensis														X																																								
Hantkenina alabamensis														X					X						X																								X		X				
Truncatulina pygmaea					X			X																										X			X	X												X					
Truncatulina americana, var. *antiqua*								X							X				X		X					X		X																										X	
Anomalina granosa, var. *dibollensis*												X					X											X																											
Anomalina affinis						X						X			X						X		X																											X					
Siphonina jacksonensis				X				X	X		X	X			X					X			X																							X								X	
Siphonina advena, var. *eocenica*	X	X							X			X		X				X			X			X		X		X																				X		X			X		X
Pulvinulina jacksonensis								X	X		X	X			X			X			X			X				X																					X					
Nonionina scapha, var.	X			X		X			X		X	X			X					X	X								X					X	X				X				X		X	X				X			X		
Nonionina umbilicatula	X							X	X			X							X				X	X		X		X																		X		X							
Nonionina hantkeni			X					X									X			X				X		X			X					X					X	X			X		X										
Nonionina advena, var. *inexcavata*								X	X	X	X	X			X														X		X		X		X								X	X											
Nonionina advena										X							X																											X										
Polystomella texana						X														X													X		X					X	X	X	X		X	X	X		X						
Nonionina whitsettensis					X	X															X													X			X	X		X	X		X	X	X		X								
Massilina sp.			X								X				X											X																											X		
Quinqueloculina sp.								X									X		X		X				X				X						X							X				X					X				
Virgulina dibollensis								X				X		X	X									X																									X			X		
Cassidulina sp.																																															X			X				
Globigerina bulloides var.																		X					X		X			X																						X	X				

26. Jackson No. 18, Sinclair Oil Company well, Damon Mound, Brazoria County, 3,688 feet.
27. P. No. 2, Rio Bravo Oil Company well, Saratoga, Hardin County, 2,897 feet.
28. Santo Domingo, Marland Oil Company well, Star County, 2,835–2,953 feet.
29. Santo Domingo, Marland Oil Company well, Star County, 2,998 feet.
30. Kelsey No. 2, Marland Oil Company well, Star County, 820 feet.
31. Kelsey No. 2, Marland Oil Company well, Star County, 1,180 feet.
32. Kelsey No. 2, Marland Oil Company well, Star County, 1,264–1,480 feet.
33. Lobo No. 5, Lobo Oil Company well, Live Oak County, 1,171 feet.
34. Ed. Matteson well, near Fant City, Live Oak County, 380–847 feet.
35. George West No. 1, Texas Company well, Live Oak County, 1,300–2,190 feet.
36. Schallert No. 3, National Oil Company well, Duval County, 2,224 feet.
37. Applin and Reed Loc. 115, Tilden Road, $\frac{8}{10}$ mile west of Callihan, McMullen County
38. Applin and Reed Loc. 124, San Antonio Road, $\frac{8}{10}$ mile north of Whitsett, Live Oak County.
39. Weisch No. 1, T. P. Coal and Oil Company, and Plateau Oil Company, Live Oak County, Texas, 1,738–63 feet.
40. Weisch No. 1, T. P. Coal and Oil Company, and Plateau Oil Company, Live Oak County, Texas, 1,827–1,908 feet.
41. Peters No. 1, Iowa-Texas Oil Company well, Duval County, 1,940–2,205 feet.
42. Westphal No. 1, Associated Oil Company well, Webb County, 1,600 feet.
43. Demonstration Farm well, Live Oak County, 1,290–1,353 feet.
44. Demonstration Farm well, Live Oak County, 1,353 feet.
45. Demonstration Farm well, Live Oak County, 1,355–1,893 feet.
46. Demonstration Farm well, Live Oak County, 2,213–61 feet.
47. Morgan O'Hearn, De la Garza No. 1, Webb County, 2,044 feet.
48. Core, Deussen A-4, Associated Oil Company well, S. Liberty, Liberty County, 3,210 feet.
49. Core, Deussen A-4, Associated Oil Company well, S. Liberty, Liberty County, 3,280 feet.
50. On Clear Creek, near White City, San Augustine County, Texas.
51. Texas Company, Fee No. 233, Sour Lake, Hardin County, 2,455 feet.
52. Texas Company, Koeler No. 32, Humble Field, Harris County, 4,051 feet.
53. Texas Company, Koeler No. 32, Humble Field, Harris County, 4,191 feet.
54. Texas Company, Koeler No. 32, Humble Field, Harris County, 4,213 feet.
55. Texas Company, Koeler No. 32, Humble Field, Harris County, 4,346 feet.

EXPLANATION OF PLATES

PLATE 6

FIG. 1.—*Haplophragmoides dibollensis* Cushman and Applin, n.sp. *a*, side view, ×35; *b*, apertural view, ×37.

FIG. 2.—*Ammobaculites hockleyensis* Cushman and Applin, n.sp. ×35. *a*, side view; *b*, apertural view.

FIGS. 3–6.—*Textularia hockleyensis* Cushman and Applin, n.sp. ×17. *a*, front view; *b*, apertural view.

FIGS. 7, 8.—*Textularia distortio* Cushman and Applin, n.sp. ×17. *a*, front view; *b*, apertural view.

FIG. 9.—*Textularia dibollensis* Cushman and Applin, n.sp., var. *humblei* Cushman and Applin, n.var. ×17. *a*, front view; *b*, apertural view.

FIGS. 10, 11.—*Textularia mississippiensis* Cushman. ×35. *a*, front view; *b*, apertural view.

FIGS. 12–14.—*Textularia dibollensis* Cushman and Applin, n.sp. ×35. *a*, front view; *b*, apertural view.

FIG. 15.—*Textularia* sp.? ×35. *a*, front view; *b*, apertural view.

FIG. 16.—*Textularia* sp.? ×35. *a*, front view; *b*, apertural view.

PLATE 7

FIGS. 1, 2.—*Bolivina gracilis* Cushman and Applin, n.sp. ×52. *a*, apertural view; *b*, front view.

FIGS. 3, 4.—*Bolivina jacksonensis* Cushman and Applin, n.sp. ×52. *a*, apertural view; *b*, front view.

FIGS. 5, 6.—*Bolivina jacksonensis* Cushman and Applin, n.sp., var. *striatella* Cushman and Applin, n.var. ×52. *a*, apertural view; *b*, front view.

FIG. 7.—*Virgulina dibollensis* Cushman and Applin, n.sp. ×52. *a*, front view; *b*, side view; *c*, apertural view.

FIG. 8.—*Bulimina jacksonensis* Cushman. ×52. *a*, front view; *b*, apertural view.

FIG. 9.—*Pleurostomella jacksonensis* Cushman and Applin, n.sp. ×52. *a*, front view; *b*, side view; *c*, apertural view.

FIGS. 10, 11.—*Bulimina* sp.? ×52. *a*, front view; *b*, apertural view.

FIGS. 12, 13.—*Nodosaria (Glandulina) laevigata* d'Orbigny, var. *ovata* Cushman and Applin, n.var. ×35. Front views.

FIGS. 14–16.—*Nodosaria jacksonensis* Cushman and Applin, n.sp. ×35. Front views.

FIG. 17.—*Nodosaria* sp.? Broken apertural end. ×35.

PLATE 8

FIGS. 1, 2.—*Cristellaria articulata* Reuss, var. *texana* Cushman and Applin, n.var. 1, adult, ×17; 2, young, ×35.

FIGS. 3, 4.—*Cristellaria limbosa* Reuss, var. *hockleyensis* Cushman and Applin, n.var. ×35. *a*, side view; *b*, front view.

FIGS. 5–7.—*Cristellaria fragaria* (Gümbel), var. *texasensis* Cushman and Applin, n.var. ×35. 5, 7, side views; 6, front view.

FIG. 8.—*Cristellaria alato-limbata* Gümbel. ×35. *a*, side view; *b*, front view.

FIG. 9.—*Cristellaria propinqua* Hantken. ×35. *a*, side view; *b*, front view.

FIG. 10.—*Cristellaria jacksonensis* Cushman and Applin, n.sp. ×35. *a*, side view; *b*, front view.

FIGS. 11–13.—*Uvigerina alata* Cushman and Applin, n.sp. ×53.

FIG. 14.—*Uvigerina topilensis* Cushman. ×35.

FIG. 15.—*Uvigerina cocoaensis* Cushman. ×35.

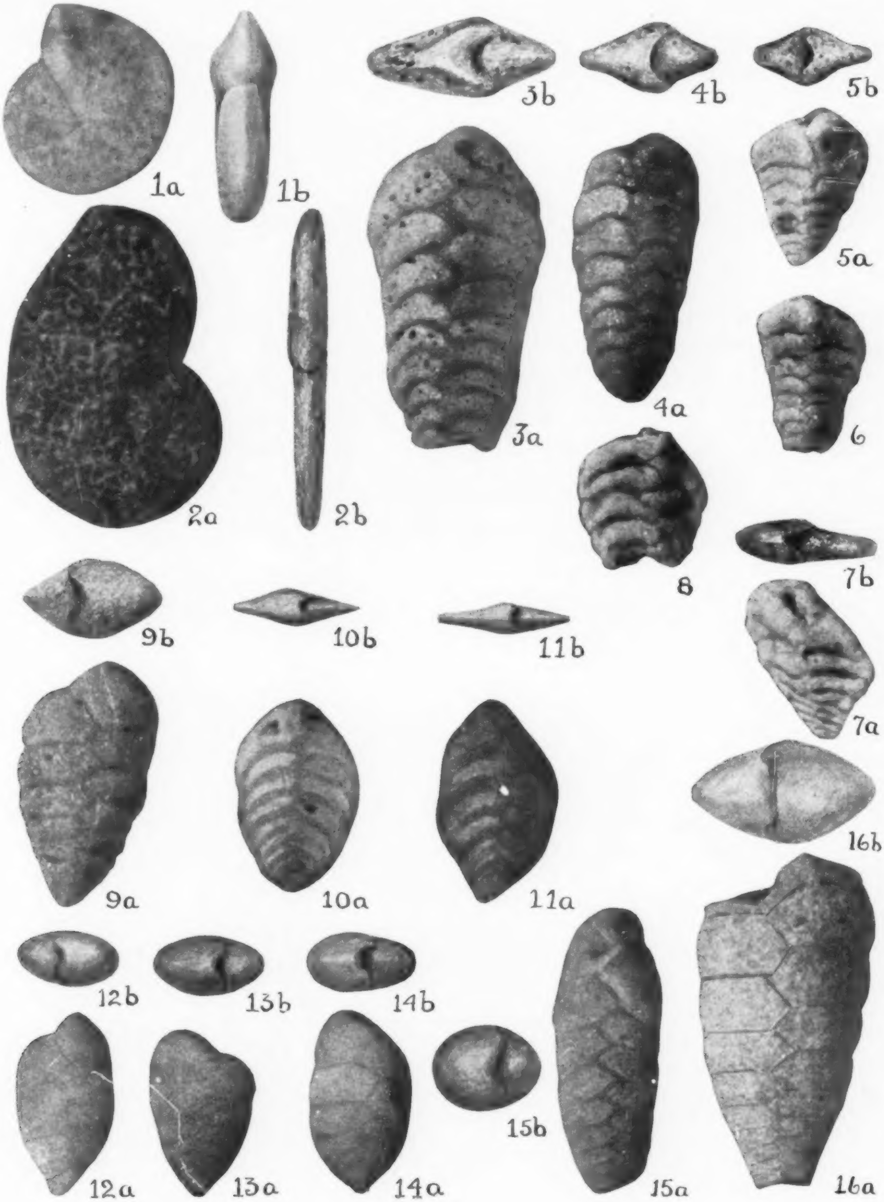
FIGS. 16, 17.—*Uvigerina gardnerae* Cushman, MS. ×35.

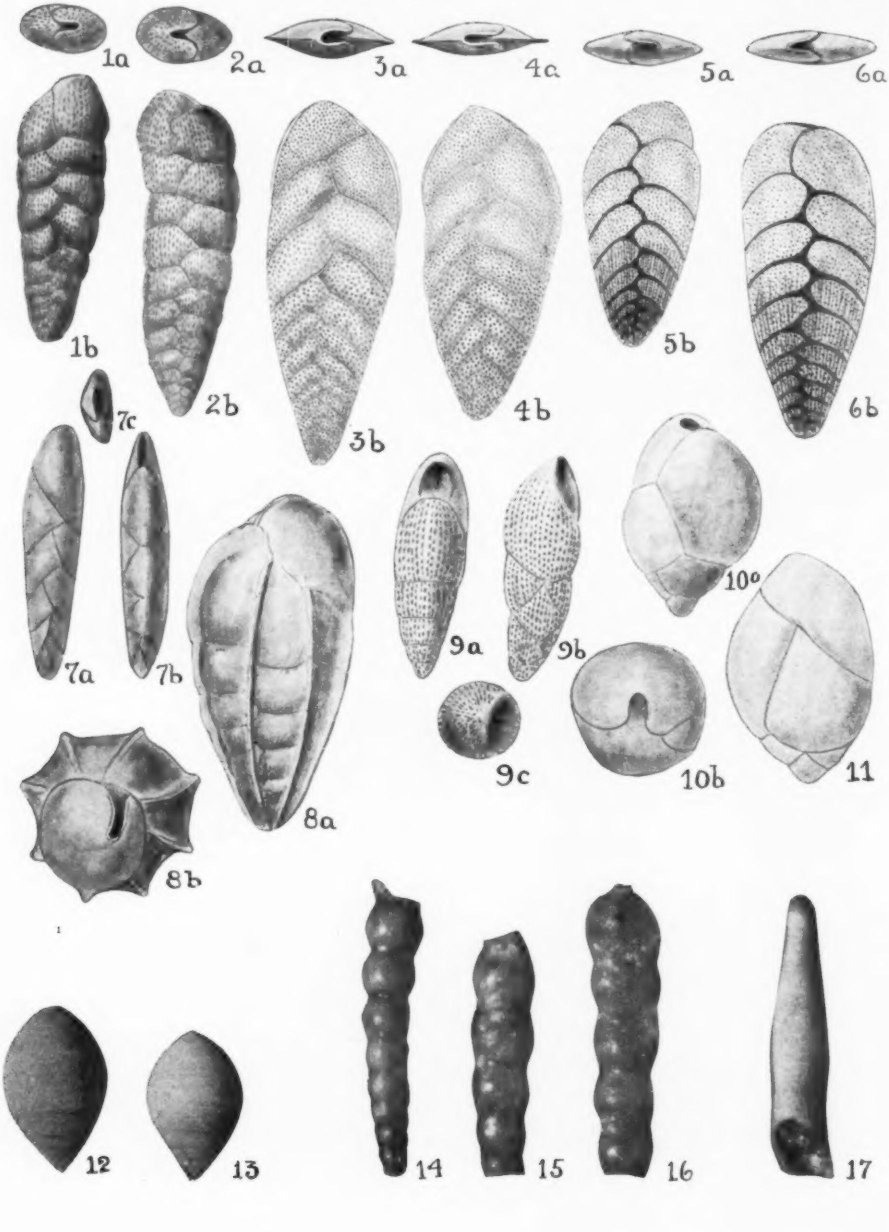
FIG. 18.—*Uvigerina gardnerae* Cushman, MS., var. *texana* Cushman and Applin, n.var. ×35.

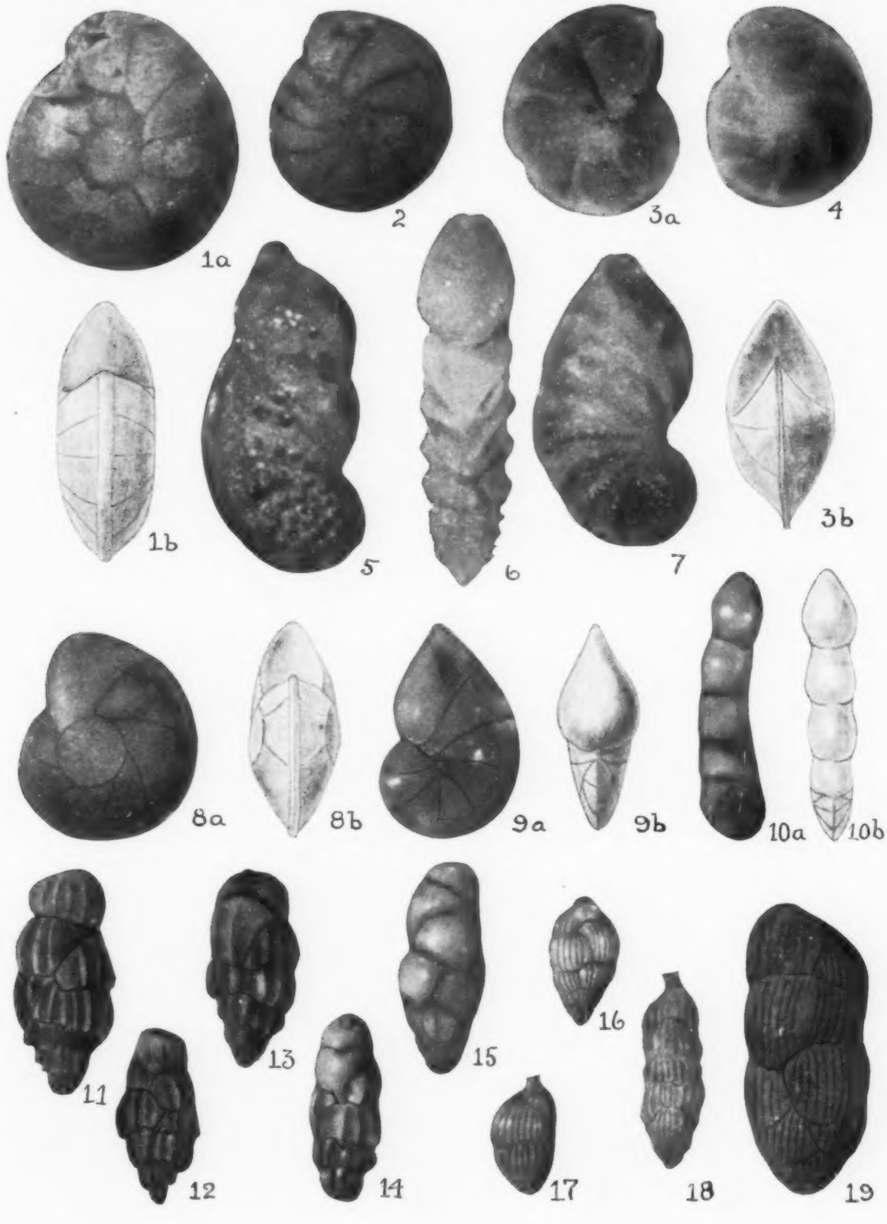
FIG. 19.—*Uvigerina dumblei* Cushman and Applin, n.sp. ×35.

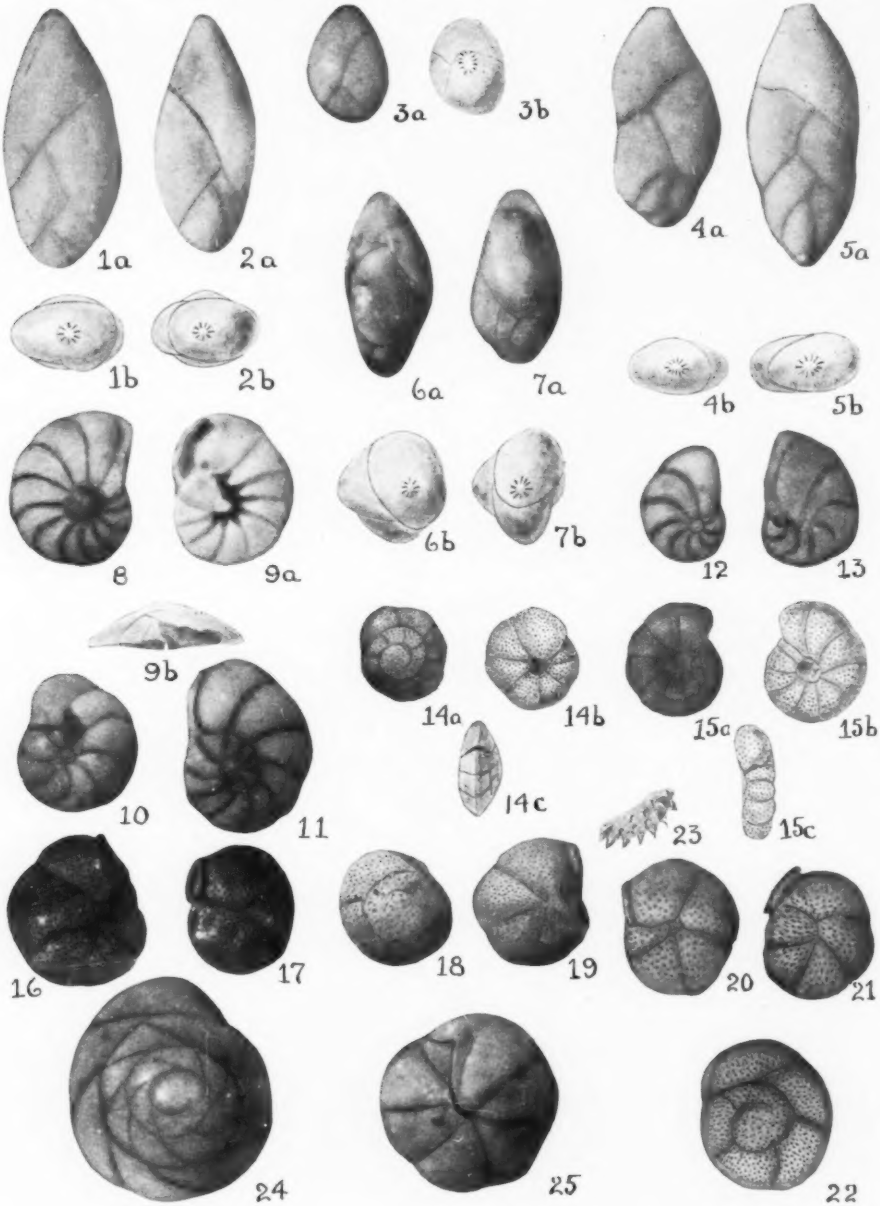
PLATE 9

FIGS. 1, 2.—*Polymorphina texana* Cushman and Applin, n.sp. ×35. 1, front view; 2, apertural view.


1a
1b
3b
4b
5b
5a
2a
2b
3a
4a
6
8
7b
9b
10b
11b
7a
16b
9a
10a
11a
12b
13b
14b
15b
12a
13a
14a
15a
16a


1a
2a
3a
4a
5a
6a
1b
2b
3b
4b
5b
6b
7c
7a
7b
8a
8b
9a
9b
9c
10a
10b
11
12
13
14
15
16
17


1a
2
3a
4
1b
5
6
7
3b
8a
8b
9a
9b
10a
10b
11
12
13
14
15
16
17
18
19


1a
2a
3a
3b
4a
5a
1b
2b
6a
7a
4b
5b
8
9a
6b
7b
12
13
9b
14a
14b
15a
15b
14c
15c
10
11
23
16
17
18
19
20
21
24
25
22

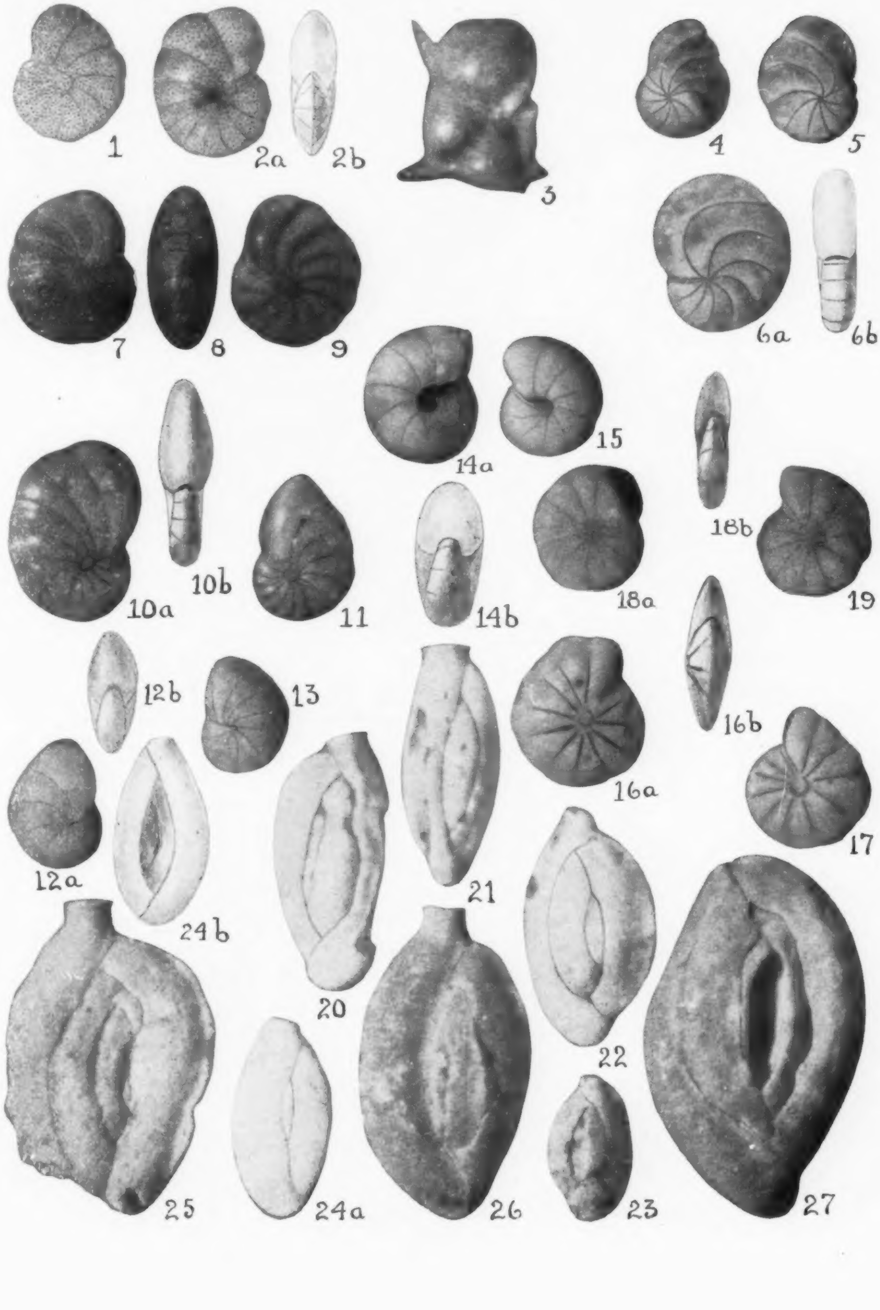

1
2a
2b
3
4
5
7
8
9
6a
6b
14a
15
10a
10b
11
14b
18a
18b
19
12b
13
16b
16a
12a
24b
21
20
17
22
25
24a
26
23
27

FIG. 3.—*Polymorphina communis* d'Orbigny, var. ×35. *a*, front view; *b*, apertural view.

FIGS. 4, 5.—*Polymorphina compressa* d'Orbigny, var. *dumblei* Cushman and Applin, n.var. ×35. *a*, front view; *b*, apertural view.

FIGS. 6, 7.—*Polymorphina austriaca* d'Orbigny, var. *io* Cushman and Applin, n.var. ×35. *a*, front view; *b*, apertural view.

FIGS. 8, 9.—*Discorbis jacksonensis* Cushman and Applin, n.sp. ×35. 8, dorsal view; 9*a*, ventral view; 9*b*, side view.

FIG. 10.—*Discorbis jacksonensis* Cushman and Applin, var. *dibollensis* Cushman and Applin, n.var. ×35.

FIG. 11.—*Discorbis jacksonensis* Cushman and Applin, var. *texana* Cushman and Applin, n.var. ×35.

FIGS. 12, 13.—*Truncatulina americana* Cushman, var. *antiqua* Cushman and Applin n.var. ×35. 12, dorsal view; 13, ventral view.

FIG. 14.—*Truncatulina pygmaea* Hantken. ×35. *a*, dorsal view; *b*, ventral view; *c*, apertural view.

FIG. 15.—*Anomalina granosa* Hantken, var. *dibollensis* Cushman and Applin, n.var. ×35. *a*, ventral view; *b*, dorsal view; *c*, apertural view.

FIGS. 16, 17.—*Siphonina advena* Cushman, var. *eocenica* Cushman and Applin, n.var. ×35. Ventral views.

FIGS. 18, 19.—*Siphonina advena* Cushman, var. *eocenica* Cushman and Applin, n.var. ×35. 18, dorsal view; 19, ventral view.

FIGS. 20–22.—*Siphonina jacksonensis* Cushman and Applin, n.sp. ×35. 20, 21, ventral views; 22, dorsal view.

FIG. 23.—*Siphonina jacksonensis* Cushman and Applin, n.sp. ×84. Margin.

FIGS. 24,25.—*Pulvinulina jacksonensis* Cushman and Applin, n.sp. ×35. 24, dorsal view; 25, ventral view.

PLATE 10

FIGS. 1, 2.—*Anomalina affinis* (Hantken). ×35. 1, dorsal view; 2*a*, ventral view; 2*b*, apertural view.

FIG. 3.—*Hantkenina alabamensis* Cushman. ×35.

FIGS. 4–6.—*Nonionina whitsettensis* Cushman and Applin, n.sp. ×35. *a*, side view; *b*, apertural view.

FIGS. 7–9.—*Polystomella texana* Cushman and Applin, n.sp. ×35. 7, 9, side views; 8, apertural view.

FIGS. 10, 11.—*Nonionina hantkeni* Cushman and Applin, n.sp. ×35. 10*a*, 11, side views; 10*b*, apertural view.

FIGS. 12, 13.—*Nonionina scapha* (Fichtel and Moll), var. ×35. *a*, side view; *b*, apertural view.

FIGS. 14, 15.—*Nonionina umbilicatula* (Montagu). ×35. *a*, side view; *b*, apertural view.

FIGS. 16, 17.—*Nonionina advena* Cushman. ×35. *a*, side view; *b*, apertural view.

FIGS. 18, 19.—*Nonionina advena* Cushman, var. *inexcavata* Cushman and Applin, n.var. ×35. 18*a*, 19, side views; 18*b*, apertural view.

FIGS. 20, 21.—*Quinqueloculina* sp.? ×35.

FIGS. 22, 23.—*Quinqueloculina* sp.? ×35.

FIG. 24.—*Quinqueloculina* sp.? ×35.

FIGS. 25–27.—*Massilina* sp.? ×35.

MINNESOTA'S OIL AND GAS POSSIBILITIES[1]

CLINTON R. STAUFFER
Minneapolis, Minnesota

ABSTRACT

Many of the geological formations of Minnesota have a porosity admirably suited to act as a reservoir rock, and there is some structure that might be favorable to the accumulation of oil and gas, but the deposits which might serve as the original source of the hydrocarbons are lacking. The sands are flooded with comparatively fresh water. Gas which is occasionally struck in shallow wells of southern Minnesota, comes from peat bogs and forest beds buried within the drift, and has no commercial value. Minnesota is justly listed among the states of no importance from the standpoint of possible oil and gas production.

INTRODUCTION

Gas[2] is sometimes struck at shallow depth in Minnesota, and often it causes hopes of commercial production. Recently several companies have been organized for the development of acreage within the state supposed to be favorable for the production of oil and gas. Some of these companies seek geological counsel, but more frequently they depend on guesses or some form of the divining rod, and eventually pay the penalty of the misinformed. It is important that reliable information be disseminated among geologists and made readily available to the public.

STRUCTURAL LOCATION

Minnesota lies directly on the northeast-to-southwest–trending axis of part of the old Laurentian Mountains of pre-Cambrian age. Since their original folding these mountains have been subjected to base-leveling, folding, faulting, various types of intrusions, and extrusive vulcanism, all antedating the Cambrian, and the whole area has probably been peneplained several times since the Cambrian. The Paleozoic and younger stratified rocks are related to this old mountain axis somewhat as the oil-bearing beds of central Kansas and north-central Oklahoma to the "granite ridge" of that

[1] Read by title at the Wichita meeting of the Association, March 28, 1925. Manuscript received by the Editor April 14, 1925.

[2] N. H. Winchell, *Geol. Survey of Minnesota*, Bull 5 (1899), pp. 1–39.

region. Since many of the older Minnesota maps show that much of the northern and western parts of the state is covered by Cretaceous deposits resting on these old mountains, it may appear, even to the geologist, that there exists in this region favorable territory for possible accumulations of petroleum.

GEOLOGICAL COLUMN

The following classification gives the present divisions, sequence,[1] and approximate thickness of the rock formations of Minnesota.

Formations	Thickness
Cenozoic	
Recent—Soils, river gravels, and flood-plain deposits	90
Pleistocene	
Wisconsin drift	400
Loess	50
Kansan drift	30
Pliocene	
LaFayette formation?	⊩ 10
Mesozoic	
Cretaceous	
Pierre shale	200±
Dakota sandstone	100±
Paleozoic	
Devonian	
Cedar Valley limestone	130
Ordovician	
Maquoketa shale	100
Galena limestone	150
Decorah shale	85
Platteville limestone	25
St. Peter sandstone	150
Shakopee dolomite	75
New Richmond sandstone	25
Oneota dolomite	160
Cambrian	
Jordan sandstone	150
St. Lawrence formation	150
Franconia sandstone	100
Dresbach formation	90
Eau Claire? shale	350±

[1] Mainly after F. F. Grout and E. K. Soper, *Geol. Survey of Minnesota*, Bull. 11 (1914), Plate 6.

Proterozoic	
Keweenawan	
Hinkley sandstone (Lake Superior or Fond du Lac sandstone)	200
Red Clastic series	2,000
Duluth gabbro	unknown
Keweenawan lava flows	unknown
Animikean	
Virginia slate (Rove, St. Louis, or Carlton slate)	3,000±
Biwabik formation (Gunflint formation)	800±
Pokegama quartzite (Sioux quartzite)	200±
Huronian	
Giants Range granite	unknown
Knift Lake slate	4,000±
Agawa formation	50±
Ogishke conglomerate	1,000±
Archaeozoic	
Laurentian	
Saganaga granite	unknown
Keewatin	
Soudan formation	500±
Ely greenstone	unknown

The accompanying geological map of the state (Fig. 1), compiled by Dr. G. M. Schwartz, shows the distribution of the major divisions given in the table.

PRE-CAMBRIAN

The pre-Cambrian is made up largely of igneous rocks or their metamorphic equivalents, but there are also associated sediments of great thickness. The sediments are much metamorphosed, and it does not seem worth while to discuss them from the standpoint of possible petroleum content. Even these rocks, however, have come in for a share of the money vainly squandered on dry holes.

PALEOZOIC

The Paleozoic sediments lie unconformably on the older rocks, chiefly on the southeast flank of the pre-Cambrian mountain mass. What lies on the northwest is not very definitely known, as that region is heavily drift-covered. There are some remnants of Ordovician rocks northwest of the Laurentian or Killarnean axis, and some areas of Cretaceous, but data from the deeper-water wells indicates that the pre-Cambrian occurs immediately under the mantle rock over most of that part of the state.

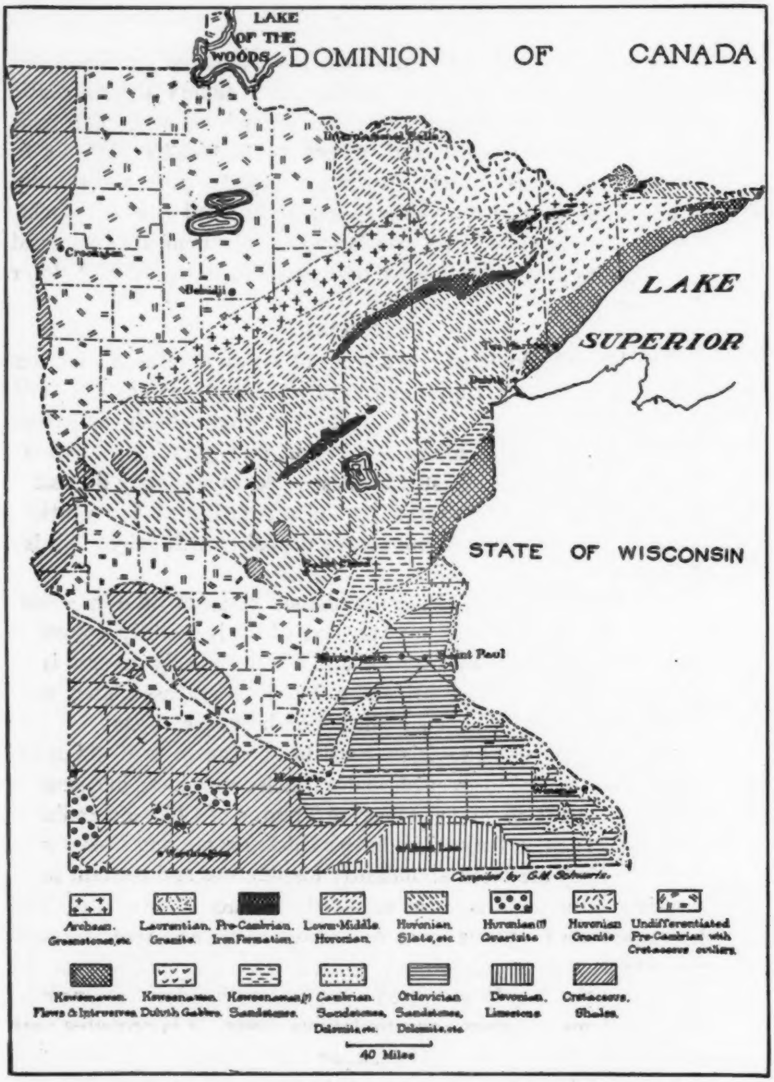


FIG. 1.—General geological map of Minnesota, *Geol. Survey of Minnesota*, Bull. 20 (1925), Fig. 2

CAMBRIAN

As far as is known the Cambrian is represented by the upper division only, and it consists of sandstone and shale with glauconitic beds and dolomitic layers. The sands are seldom well cemented; many of them are white and, where unfossiliferous, difficult to distinguish from each other. They are of medium grain and contain an abundant pore space which makes them good reservoir rocks. Most of them are filled with artesian water, and none are associated with deposits that might furnish hydrocarbons in the form of either oil or gas.

ORDOVICIAN

The lower Ordovician is made up of massive, often arenaceous and cherty dolomite, containing locally more or less cavities filled with crystals of quartz, and white to brown or reddish sandstone, evenly bedded and marked by rectangular jointing. Whatever traces of life may have existed in these rocks as originally deposited have been almost obliterated by dolomitization or by solution. There is no associated carbonaceous deposit which might furnish oil or gas.

The well-known St. Peter sandstone consists of a medium-grained white to yellowish quartz sand which is scarcely cemented at all. It is an ideal reservoir rock, and where properly covered is an important source of artesian water, but it is not associated with sediments that might have supplied it with hydrocarbons.

The succeeding Ordovician consists of blue to buff dolomitic limestones and blue to greenish shales which correspond, in a general way, to the great oil- and gas-bearing Trenton of Ohio and Indiana. In Minnesota these formations have a thickness ranging from 150 to 200 feet. They are often abundantly fossiliferous and contain some organic matter, but, as far as explored, no trace of oil or gas. The dolomitic beds are probably as well suited to act as a reservoir rock as where commercial oil or gas is obtained, but the beds lie near the surface in the highly dissected area of southeastern Minnesota, where no hope of present accumulations exists. It is probable that such accumulations never did exist, and it is certain that if they did, drainage has long since dissipated them.

The Maquoketa shale consists of about 100 feet of gray to drab shale and shaly limestone. Although it is sometimes carbonaceous,

it often caps the hills and is in no way suited to petroleum production, unless it should be in the south-central part of the state, where it is overlain by later beds. Unfortunately, even in that region it was the surface formation for a long period during which marked erosion took place, thus allowing any oil or gas to escape.

DEVONIAN

The Devonian in Minnesota consists of gray to buff porous dolomitic limestone, which in some places passes into highly calcareous white limestone. The limestone, about 130 feet thick, at most, covers a small area in the southern part of the state, where it lies immediately under the drift or is overlain by patches of Cretaceous, and rests disconformably on the Maquoketa, where the base may be seen. As the Devonian extends to the westward, however, it probably overlaps the edge of the Maquoketa and lies on older formations. Although the Devonian is sufficiently porous to act as a reservoir, in many cases, it shows no signs of either oil or gas, and probably never contained them. It is not associated with shales that might have given rise to such products, and, like most of the other Minnesota formations, does not even have an odor of petroleum.

CRETACEOUS

After prolonged erosion, beds of Cretaceous age were laid down over nearly the whole state, thus covering unconformably the different older rocks with a deposit of sandstone, shale, and occasional thin lignite beds. Over much of the state these now exist as scattered remnants of no consequence in the present consideration. In part of the western and northwestern region, however, continuous beds of Cretaceous age are believed immediately to underlie the drift and to dip into the Moose Jaw synclinorium. It is certain that Cretaceous beds crop out along the upper Mississippi and some of its tributaries, while remnants overlie the iron formations on the Mesabi Range. Also some of the deeper-water wells of the northwest region have penetrated the entire thickness of the drift and revealed Cretaceous beds beneath. If there is any region within the state which is in any sense promising as a possible oil- or gas-producing area, it would appear to be this northwestern portion. And yet it is so heavily drift-covered that the true nature of its bed rock cannot be

known definitely. According to available information, the Cretaceous consists of a blue clay overlying a white sand. At no place are these rocks suggestive of petroleum production.

PLEISTOCENE

The most important of the superficial deposits is the drift which covers like a blanket the greater part of the state. Loess deposits are widespread, and in the southeastern part of the state are certain high gravels which may represent the Lafayette formation.

Glacial drift is surely an unpromising source for oil and gas, yet it is these deposits that have been chiefly responsible for "indications" that from time to time cause considerable excitement, as when gas is struck in drilling for water. Occasionally, as during the summers of 1923 and 1924, some of these wells penetrate a gas pocket with very high pressure, sufficient, in fact, to "bounce the tools," and even throw out quantities of sand and other rock débris. The gas may utterly spoil the well, but it usually subsides within a few days. A number of such occurrences have been examined, and the gas, all proves to come from a slight depth, wholly within the drift, being derived from ancient peat bogs and forest beds buried within the drift. After observing one of these "strikes," there is little wonder that those unfamiliar with the conditions under which real production occurs should occasionally be misled, but of course the gas can have no commercial value, as it soon gives out and further drilling does not increase its flow.

SUMMARY

Minnesota is an unfavorable area for oil and gas prospecting. The insignificant puffs of gas from wells in the southern part of the state are derived from buried forests, peat bogs, or old lake-beds within the drift, and can never be expected to yield commercial production. The sands of the bed rock in this region, though excellent reservoirs, are flooded with fresh water, and any petroleum products that may have existed in the area have long since escaped. The only areas of possible production lie in the Cretaceous-covered western and northwestern parts of the state, where the drift covering is so thick and the probabilities of commercial production so small that it is not practical to give the region any consideration.

GEOLOGICAL NOTES

THE KEVIN-SUNBURST OIL FIELD, MONTANA[1]

The Kevin-Sunburst oil field of Montana has made slow but steady progress toward the position of a major field. Discovered in 1922, it was the first field in the United States to yield a truly important amount of oil from Jurassic strata, and while at present small quantities of oil may be produced from the Sundance formation of Jurassic age in Wyoming, the Kevin-Sunburst field, which draws its major production from the basal sand of the Ellis formation, remains the only important field that depends on the Jurassic.

The field is on a great, low dome, with the oil apparently perched on the northwest side of the dome. No explanation for this position of the oil and its apparent absence on the other flanks and the crest of the dome is offered in this paper, nor, so far as the reviewer is aware, in any other discussion of the field that has been published. This "perched" position of the oil is by no means unique, but the Sunburst field is an example on a grand scale of what has been observed on many much smaller domes and anticlines, and it may prove to be an especially favorable place to look for an explanation of this habit that has been observed in so many oil fields.

Although the deepest production apparently comes from the basal sand of the Jurassic, there has been persistent search for deeper horizons, and one well on the very crest of the structure was drilled to a depth of 4,445 feet, proving the existence of 770 feet of Madison limestone (Lower Mississippian), 335 feet of limestones that are probably Devonian, 275 feet of anhydrite that may be Silurian, and 1,585 feet of limestones, shales, anhydrites, and sands that are Silurian or older.

K. C. Heald

AGE OF PRODUCING HORIZON, RICE COUNTY, KANSAS

Attention was called to the Rice–Reno County district of central Kansas by the completion of a 140-barrel well on the Welch farm in the southeast corner of the SW. ¼ of the NW. ¼ of Sec. 35, T. 20 S., R. 6 W., in March, 1924. The oil occurs in a white to gray chert, encountered at

[1] *Press Notice*, United States Geological Survey, January 12, 1926.

a depth of 3,370–3,400 feet in the discovery well. Cuttings recovered from this zone are very similar in color and general appearance to "chat" samples so characteristic of the upper surface of the Mississippian in Kansas.

By common consensus of opinion, geological workers in this region have maintained that this cherty zone is of Mississippian or Ordovician age. Their conclusions are based upon the "chatty" character of the samples, rather than progressive well-log correlations and a knowledge of the distribution of chert-bearing beds in the lower Pennsylvanian section.

A progressive well-log correlation, extending from the "granite ridge" westward into this area, places the oil-bearing cherty zone in the Fort Scott ("Oswego") horizon. Locally, over the axis of the "granite ridge" in Chase County, a part of the Upper Cambro-Ordovician, all of the Mississippian, and a part of the lowest Pennsylvanian (usually Cherokee) are missing; but within short distances down the east and west limbs of this ridge the normal Pennsylvanian and pre-Pennsylvanian sequence of formations is again present. All deep tests in Harvey County, from east to west, report from 100 to 330 feet of Cherokee shale beneath the "Oswego," resting upon limes and sandy limes of Mississippian age.[1] This Harvey County section continues westward into the Reno–Rice County district. Here several tests have been drilled below the oil-bearing "chat" zone; and, as eastward in Harvey County and northward in Ellsworth County, the "chat" zone is underlain by a thick shale section.[2] Showings of oil and gas, even in commercial quantities, in the "Oswego" of southeast Kansas and northern Oklahoma are common. Chert can be found in the limestone at this horizon along its outcrop, though it is seldom reported by the driller. Age of strata cannot be based upon physical appearance of well cuttings alone, nor upon faunal evidence alone.

HENRY A. LEY

[1] A test in Sec. 26, T. 24 S., R. 2 E., encountered 101 feet of Cherokee shale (2,784–2,885 feet), 315 feet of Mississippi lime (2,885–3,200 feet), 85 feet of Chattanooga shale (3,200–3,285 feet), and 37 feet of Cambro-Ordovician rocks (3,285–3,322 feet).

[2] The Wernet test in Sec. 14, T. 14 S., R. 6 W., Rice County, reports the "chat" zone ("Oswego"), at 3,290 to 3,368 feet; black shales (Cherokee), from 3,368 to 3,615 feet; and lime (Mississippian), 3,615 to 3,655 feet.

THE SHERIDAN TEST, ELLSWORTH COUNTY, KANSAS

Bramlette[1] concludes that members of the cherty zone penetrated at a depth of 3,270–3,370 feet in the Sheridan well, drilled in Sec. 21, T. 15 S., R. 6 W., Ellsworth County, Kansas, are Mississippian beds. Well-log correlations extending from the "granite ridge" in Chase County westward through Marion and Harvey counties, into the Reno-Rice County area, and thence northward through Rice into Ellsworth County to the Sheridan test, do not substantiate this conclusion.

All evidence indicates that this cherty zone is the Fort Scott ("Oswego") limestone member of the Marmaton formation. It is not at all uncommon to find chert in this member along its outcrop in Kansas and Missouri.[2] The sample obtained at a depth of 3,500 feet in this cherty zone, containing abundant Pennsylvanian fauna, probably occurred in place and was not, as Bramlette maintains, a caved sample of no significance. If so, there can be no question of the Pennsylvanian (Cherokee) age of the underlying shales to a depth of 3,632 feet. From this point to the bottom of the hole (4,007 feet) the section is Mississippian or Cambro-Ordovician.

HENRY A. LEY

[1] M. N. Bramlette, "A Subsurface Correlation of the Stratigraphic Units from Russell County to Marion County, Kansas," *Geol. Survey of Kansas*, Bull. 10, Part 2 (1925), pp. 92–93.

[2] Henry Hinds and F. C. Greene, "The Stratigraphy of the Pennsylvanian Series in Missouri," *Missouri Bureau of Geol. and Mines*, Vol. 13, Second Series, pp. 68–69.

REVIEWS AND NEW PUBLICATIONS

OIL FINDING BY GEOPHYSICAL METHODS

In the October number of the *Journal of the Institution of Petroleum Geologists*, Mr. W. H. Fordham discusses "Oil Finding by Geophysical Methods."[1] He considers magnetic, electric, and gravitational methods, but nearly the entire paper is on the theory and application of the torsion balance. We quote the last few paragraphs:

"The general conclusions reached from a study of geophysical literature are:

"1. That oil deposits do not appear to possess sufficiently definite physical properties, either magnetic, electric or gravitational, as to enable them to be directly discovered, except under rather uncommon circumstances.

"2. That certain tectonic configurations, accompanying accumulations of oil, have gravitational properties which enable them to be found by means of the Eötvös balance, and that these tectonic configurations are more common than is, at present, realised.

"3. That further investigation may show that various tectonic configurations, accompanying accumulations of oil, can be rapidly, though possibly merely approximately, located, through their magnetic or electric properties."

A good bibliography on the subject is given at the end of the paper.

FREDERIC H. LAHEE

[1] Vol. 11, No. 52, pp. 448–70 (London).

THE ASSOCIATION ROUND TABLE

ANNOUNCEMENTS OF THE FOURTEENTH INTERNATIONAL GEOLOGICAL CONGRESS

The second *Circular of Announcements* covering the Fourteenth International Geological Congress to be held in Spain is of interest to all geologists, but is of special importance to all those who contemplate attending the meeting.

The formal scientific and business meetings of the Congress will be held in Madrid, May 24–31, 1926.

Consistent with the traditional democracy of previous geological congresses, membership requires no professional title nor credentials, but participation in the excursions is reserved to official delegates of the different nations, geologists, geographers, mining engineers, and all persons engaged in the study or application of any branch of geology. The membership fee is 30 *pesetas*, which covers admission to the sessions and receipt of the memoirs of the Congress. The present exchange value of the *peseta* is 14.12 cents.

Following the custom established at a number of preceding congresses, the coming session will be marked by the presentation and issue of an outstanding monograph relating to some important mineral commodity or commodities, which for this Congress will cover the world's resources in phosphates and pyrites. American geologists will recall the invaluable report on "The Coal Resources of the World" similarly issued by the Twelfth International Congress which met at Toronto in 1913.

Additional topics which will be made the subjects of special discussion at Madrid include: (*a*) "Geology of the Mediterranean"; (*b*) "Cambrian and Silurian Faunas"; (*c*) "Geology of Africa and Its Relation to That of Europe"; (*d*) "Tertiary Invertebrates"; (*e*) "Hercynian Folds"; (*f*) "Tertiary Foraminifera"; (*g*) "Modern Theory of Metallogeny"; (*h*) "Vulcanism"; and (*i*) "Geophysical Studies, Their Application to Geology, and the Necessity of Unification of Gravimetric Methods."

Contributions may be made in English, French, German, or Spanish, and abstracts or summaries, which in length should not exceed one page of printed text, should be submitted to the general secretary on or before April 1. Final manuscripts should be sent typewritten in duplicate and in corrected copy.

The excursions planned to cover the principal geologic provinces, mining centers, types of resources, and special geologic features are of exceptional interest from many points of view and reflect the pains taken by the Spanish government to make this Congress most enjoyable as well as successful. Most of them will take place in advance of the Congress, a few short ones during the

Congress, and several longer ones after the Congress. The earliest begins on May 5. Though mainly geologic in purpose, matters of scenic and historical interest are also included. Following is a mere list of these excursions, the various and attractive objectives, the itineraries, and other details of which are given in the second *Circular:*

A-1.—Gibraltar, Seville, Algeciras, and northern Morocco, covering iron deposits of Melilla, the Tertiary of the lower Guadalquivir, Tetuan, the Mount Uixan ore deposits, and other points of special interest; twelve days, starting May 10–575 *pesetas*.

A-2.—Structure and petrography of the mountains of Ronda, via Malaga, the metamorphic area of "Los Llanos del Jaunar," and Seville; six days, starting May 14—400 *pesetas*.

A-3.—Mining regions of Linares and Huelva, the richest lead and copper districts of Europe, including the famous Rio Tinto mines, ten days, starting May 13—415 *pesetas*.

A-4.—Tectonic study of the Guadalquivir Valley and petrology and paleontology of the Cordova Mountains; seven days, starting May 16—315 *pesetas*.

A-5.—Tectonics, stratigraphy, and paleontology of the Andalusian Mountains from the border of the Iberian Plateau to the Sierra Nevada, an excursion of notable paleontologic, historic, and artistic importance, including Granada and the Alhambra; twelve days, starting May 11—570 *pesetas*.

A-6.—The Continental Tertiary of the vicinity of Burgos; two days, starting May 20—160 *pesetas*.

A-7.—Review of the volcanic, petrologic, historical, and scenic features of the Canary Islands; via Seville, Cadiz, and South American steamer; seventeen days, starting May 5—800 *pesetas*.

B-1.—Mercury mines of Almaden; one day, starting May 26—15 *pesetas*.

B-2.—Orogenic, petrologic, and glacial features of the Guadarrama Mountains; one day (not fixed)—40 *pesetas*.

B-3.—Motor-car excursion for examination of the Continental Tertiary and Castilian Steppes of the River Tajo Basin, with visit to the royal palaces and gardens at Aranjuez; one day—50 *pesetas*.

The excursions following the Congress include:

C-1.—Paleozoic series and coal-mining of the Asturias district, with examination of manganese mines at Covadonga, and inspection of noted tectonic, scenic, and historical features en route; six days, starting June 1—275 *pesetas*.

C-2.—Iron deposits of Bilbao—especially for mining engineers; three days, following the Asturias excursion and starting June 8—200 *pesetas*.

C-3.—Potash-bearing basin of Catalonia and the central Pyrenean Mountains via Barcelona, Monserrat, Manresa, Solsona, Artesa, Isona, and other points of varied geologic and historic, scenic, or industrial significance; eleven days, starting June 1—475 *pesetas*.

C-4.—Potash basin of Catalonia and the eastern Pyrenees, with especial attention to the Cretaceous formations and the volcanic system of Olot. This excursion, which overlaps the preceding, covers the lignitic basin of Figols; the review of various Carboniferous, Triassic, and Cretaceous sections; tectonic features connected with the Mediterranean region; the volcano of Lacot; and the mud volcanoes and sulphur springs in the vicinity of Castellfullit and Bañolos; ten days, starting June 6—400 *pesetas*.

C-5.—The tectonics, the Triassic and Tertiary stratigraphy and paleontology, the grottoes, caves, coal mines, etc., of the Balearic Islands; eleven days, starting June 4, but overlapping on excursions C-3 and C-4 for the first three days—430 *pesetas*.

It is important to note that (*a*) only members of the Congress may participate in excursions; (*b*) the number of participants in each excursion is limited, on which account early applications are necessary for the completion of arrangements; (*c*) applications for participation in excursions preceding the Congress must be in the secretary's hands on or before the first of April; (*d*) period of admission to excursions taking place during the Congress (group *b*) and after the Congress (group *c*) expires May 1; (*e*) the excursion fee includes the guidebook for that excursion, and all expense, including voyages, hotels, meals, tips, etc., of the ordinary character. Excursion reservations are payable in advance.

Further information, particulars, and conditions will be found in the second *Circular*, which is soon to be followed by a third *Circular*, covering such matters as hotels and guidebooks. All correspondence should be addressed to the Secretary of the Fourteenth Geological Congress, Instituto Geológico, Plaza de los Mostenses, 2, Madrid, Spain.

PROFESSIONAL DIRECTORY

ADDRESS: WILLIAM B. HEROY, ADVERTISING MANAGER, ROOM 1500, 45 NASSAU ST., NEW YORK CITY

D. DALE CONDIT

CHIEF GEOLOGIST IN INDIA

WHITEHALL PETROLEUM CORPORATION LTD.
SHILLONG, ASSAM, INDIA
AND
53 PARLIAMENT STREET, LONDON, S.W. 1
(NO OUTSIDE WORK)

HUNTLEY & HUNTLEY

PETROLEUM GEOLOGISTS
AND ENGINEERS

L. G. HUNTLEY — STIRLING HUNTLEY

FRICK BUILDING, PITTSBURGH, PA.

R. A. CONKLING

CONSULTING GEOLOGIST
PETROLEUM ENGINEER

COLCORD BUILDING — OKLAHOMA CITY, OKLA.

GEO. C. MATSON

GEOLOGIST

408 COSDEN BLDG. — TULSA, OKLA

JAMES L. DARNELL

ENGINEER

170 BROADWAY — NEW YORK CITY

DABNEY E. PETTY

GEOLOGIST

SAN ANTONIO — TEXAS

RALPH E. DAVIS

ENGINEER

GEOLOGICAL EXAMINATIONS
APPRAISALS

1710 UNION BANK BLDG. — PITTSBURGH, PENN

DEWITT T. RING

GEOLOGIST

404 ARMSTRONG BLDG. — EL DORADO, ARK.

FRANK W. DEWOLF

CHIEF GEOLOGIST
HUMPHREYS CORPORATION

NOT OPEN FOR CONSULTING ENGAGEMENTS

501 MASON BUILDING — HOUSTON, TEX.

EUGENE WESLEY SHAW

GEOLOGIST

170 BROADWAY — NEW YORK

AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

OFFICERS FOR 1926-1927

JAMES H. GARDNER, *Retiring President*
Tulsa, Oklahoma

E. L. DEGOLYER, *President*
New York City

R. S. McFARLAND, *Vice-President*
Tulsa, Oklahoma

RAYMOND C. MOORE, *Editor*
Lawrence, Kansas

CHARLES E. DECKER, *Secretary-Treasurer*
Norman, Oklahoma

REGIONAL DIRECTORS

Eastern:
ROSWELL H. JOHNSON, University of Pittsburgh, Pittsburgh, Pennsylvania.

North Mid-Continent:
W. B. WILSON, Box 2044, Tulsa, Oklahoma.

South Mid-Continent:
R. B. WHITEHEAD, 702 Magnolia Building, Dallas, Texas.

Arkansas-Louisiana:
A. F. CRIDER, 821 Ontario St., Shreveport, Louisiana.

Gulf Coast:
DAVID DONOGHUE, West Building, Houston, Texas.

Rocky Mountain:
THOMAS S. HARRISON, 1106 First National Bank Building, Denver, Colorado.

Pacific Coast:
STEPHEN H. GESTER, 607 Standard Oil Building, San Francisco, California.

Mexico:
WALTER M. SMALL, Apartado 76, Tempico, Mexico.

Venezuela:
FRED H. KAY, Apartado 1, Caracas, Venezuela.

THE PACIFIC SECTION

OFFICERS

E. F. DAVIS, *Chairman*
401 Higgins Building, 2nd and Main Streets, Los Angeles, California

C. M. WAGNER, *Secretary-Treasurer*
Care of General Petroleum Corporation, Higgins Building, 2nd and Main Streets, Los Angeles, California

MEMBERSHIP

Membership in the Pacific Section is restricted to members of the A.A.P.G. in good standing, residing in the Pacific Coast States. Dues of $2.00 per year are payable to the Secretary-Treasurer of the Pacific Coast Section. Members of the A.A.P.G. transferring to the Pacific Coast are cordially invited to become affiliated with the local section, and to communicate their change of address promptly to the Secretary-Treasurer of the Pacific Section.